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RESEARCH MEMORANDUM

PRELIMINARY AIR-FLOW AND THRUST CALIBRATIONS OF SEVERAL CONICAL COOLING-AIR EJECTORS WITH A PRIMARY TO SECONDARY TEMPERATURE RATIO OF 1.0

II - DIAMETER RATIOS OF 1.06 AND 1.40

By W. K. Greathouse and D. P. Hollister

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Cleveland, Ohio

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NATIONAL ADVISORY COMMITTEE
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RESEARCH MEMORANDUM

PRELIMINARY AIR-FLOW AND THRUST CALIBRATIONS OF SEVERAL CONICAL COOLING-AIR EJECTORS WITH A PRIMARY TO SECONDARY TEMPERATURE RATIO OF 1.0

II - DIAMETER RATIOS OF 1.06 AND 1.40

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SUMMARY

An investigation was made of the performance of nine conical cooling-air ejectors at primary jet pressure ratios from 1 to 10, secondary pressure ratios to 4.0, and a temperature ratio of unity. This phase of the investigation was limited to conical ejectors having shroud-exit to primary-nozzle-exit diameter ratios of 1.06 and 1.40, with several spacing ratios for each.

The experimental results indicated that the pumping range and amount of cooling-air flow obtained with a 1.06-diameter-ratio ejector were relatively small for cooling purposes but that the maximum possible thrust loss, which occurred with no secondary flow, was only 7 percent of convergent-nozzle thrust. The 1.40-diameter-ratio ejector produced a large cooling-air flow and showed a possible thrust loss of 29.5 percent with no cooling-air flow. Thrust gains were attained with ejectors of both diameter ratios at secondary pressure ratios greater than 1.0. The limiting primary pressure ratio below which an ejector can operate at a specific secondary pressure ratio (cut-off point) may be estimated for various flight conditions from data contained herein.

INTRODUCTION

The air ejector is currently being used as a simple, light-weight device to pump tail-pipe cooling air for turbojet installations and is being considered as a means of cooling high-temperature afterburners. Various combinations of ejector geometry can be used to pump a prescribed amount of cooling air, but the respective losses or gains in jet thrust may be vastly different. Numerous theoretical investigations have been made to evaluate ejector performance, but the available experimental information is in general limited to low pressure ratios or does not include adequate thrust data.

In order to extend the range of existing cooling-air-flow and thrust-performance data, the NACA Lewis laboratory is conducting an experimental investigation of cooling-air ejector models. The purpose of this report is to present experimental results for a limited number of conical-type ejector configurations operating over a wide range of conditions and thereby to supplement the data obtained in an earlier phase of this investigation (reference 1).

Thrust and pumping characteristics over a range of primary pressure 2623
ratios P_p/p_0 from 1 to 10 and secondary pressure ratios P_s/p_0 to 4.00 are presented herein for conical ejectors having diameter ratios D_s/D_p of 1.06 and 1.40, with several spacing ratios S/D_p for each. Data are presented in terms of secondary to primary weight-flow ratio and gross ejector-thrust to primary-nozzle-thrust ratio. The investigation was conducted with a convergent primary nozzle and a conical secondary shroud, with unheated air at a temperature of approximately 80° F.

APPARATUS AND PROCEDURE

The nomenclature used for the conical-ejector investigation is listed in figure 1, and the apparatus is schematically shown in figure 2. All apparatus, instrumentation, and methods of performing the tests were exactly as described in reference 1 for an earlier phase of the present ejector program. The only change was, of course, the geometry of the ejector shrouds. Two shrouds with different exit diameters and the same half-cone angle of 8° were used to provide diameter ratios D_s/D_p of 1.06 and 1.40. The spacing ratio S/D_p was varied over the following range of values for each diameter ratio by inserting spacer rings and gaskets between the approach pipe and the shroud:

Diameter ratio, D_s/D_p	Spacing ratio, S/D_p						
1.06	0.165	0.386	0.572	0.776	0.977	----	----
1.40	-----	.370	-----	.803	-----	1.19	1.59

Performance of each ejector configuration was investigated over a range of primary pressure ratios P_p/p_0 from 1 to about 10 with various constant secondary pressure ratios P_s/p_0 up to 4.00. Additional tests were performed for zero secondary air flow with the upstream secondary passage blocked. Also a calibration of the primary nozzle with the shroud removed was obtained to determine flow coefficients and primary nozzle thrust over a range of pressure ratios.

RESULTS AND DISCUSSION

Pumping Characteristics

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Experimental performance data for the conical cooling-air ejector are presented in figures 3(a) to 3(e) and in figures 3(f) to 3(i) for diameter ratios of 1.06 and 1.40, respectively. These plots show the effect of primary pressure ratio P_p/p_0 on ejector weight-flow ratio W_s/W_p for various constant secondary pressure ratios P_s/p_0. The primary pressure ratio at which the weight-flow-ratio curves decreased to zero was determined with the upstream secondary flow passage blocked (zero secondary flow) and is herein referred to as the cut-off point. The cut-off point thus defines the limiting primary pressure ratio at which an ejector can operate for a specific secondary pressure ratio. Operation beyond this point in actual aircraft installations will result in a backflow from the primary jet into the secondary system.

Most of the configurations investigated exhibited typical ejector characteristics and trends similar to those of the performance characteristics obtained in an earlier part of this investigation (reference 1) for diameter ratios of 1.10 and 1.21. Pumping characteristics of the two largest spacing ratios investigated for the largest diameter ratio were, however, somewhat different from those of the other ejector configurations. For both of these configurations (figs. 3(h) and 3(i)) two distinct regions of peak weight-flow ratio occurred for secondary pressure ratios of both 0.90 and 0.95.

The pumping range of the 1.06-diameter-ratio ejector was indicated to be small for secondary pressure ratios less than 1.0, and only low values of secondary air flow (low weight-flow ratio) were obtained in this range (figs. 3(a) to 3(e)). Thus, a conical ejector of 1.06 diameter ratio can be satisfactorily used only in installations that have relatively small cooling requirements. As shown in figures 3(f) to 3(i) the 1.40-diameter-ratio ejector can supply a much larger secondary air flow over a wider range of primary pressure ratios than can the 1.06-diameter-ratio ejector.

Effect of Spacing Ratio on Pumping

The variation of ejector weight-flow ratio with spacing ratio is presented in figure 4 for the diameter ratios of 1.06 and 1.40. The curves are cross-plotted for three values of primary pressure ratio, 2.00, 3.50, and 9.00, which may be considered representative of take-off, high subsonic, and supersonic flight conditions, respectively. Only small variations in weight-flow ratio with spacing ratio occurred for the 1.06-diameter-ratio ejector, although regions of maximum pumping are indicated (fig. 4(a)). The spacing ratio corresponding to these maximum regions was generally unchanged by an increase in secondary pressure ratio up to 1.0, but was decreased slightly by an increase in secondary pressure ratio above 1.0. The region of maximum weight-flow ratio also shifted slightly with changes in primary pressure ratio. 2623 Nevertheless, near optimum pumping performance may be approximated over a reasonable range of flight conditions with the 1.06-diameter-ratio ejector at a fixed spacing ratio.

With a diameter ratio of 1.40, rather large variations in weight-flow ratio occurred as spacing ratio was changed (figs. 4(d) to 4(f)). The spacing ratio corresponding to a region of maximum pumping changed only slightly with secondary pressure ratio, although the spacing ratio at which maximum pumping occurred decreased sharply as primary pressure ratio was increased. Therefore, a 1.40-diameter-ratio ejector with a fixed spacing ratio that has good pumping characteristics at one flight condition may have less desirable characteristics at another condition. At a primary pressure ratio of 9.00 and secondary pressure ratios less than 3.00 the pumping characteristics were found to be poor at spacing ratios near 1.0, as shown by the region of minimum weight-flow ratio in figure 4(f).

Effect of Diameter Ratio on Pumping

In figure 5, which was cross-plotted from the preceding figures and similar figures in reference 1, the variation in ejector weight-flow ratio with diameter ratio D_s/D_p is shown for fixed values of spacing ratio and primary pressure ratio. For secondary pressure ratios greater than 1.0, the weight-flow ratio continuously increased with increasing diameter ratio because at a given primary pressure ratio the restriction to secondary flow was reduced when the exit area of the shroud became greater. At secondary pressure ratios less than 1.00, the weight-flow ratio maximized at an optimum diameter ratio, because the primary jet filled a smaller percentage of the shroud exit at larger diameter ratios and thereby increased the tendency for inflow to occur from the exhaust tank into the secondary system. The diameter ratio at which maximum weight-flow ratio occurred was changed only slightly by changes in secondary pressure ratio or spacing ratio but increased as primary pressure ratio was increased.

Conditions at the cut-off point are cross-plotted (from previous figures and reference 1) in figure 6 to show how variations in diameter ratio and spacing ratio affect the operational limits of the conical-type ejector. The lines of constant secondary pressure ratio represent the variation of the cut-off point with diameter ratio. At a given spacing ratio and secondary pressure ratio, a secondary air flow greater than zero was obtained only at primary pressure ratios below the corresponding cut-off point indicated. It should be noted that increasing diameter ratio greatly increased the primary pressure ratio at which cut-off occurred; for example, at a spacing ratio of 0.40, diameter ratio of 1.10, and secondary pressure ratio of 1.50 the cut-off point occurred at a primary pressure ratio of 5.82. Increasing the diameter ratio to 1.20 shifted the cut-off point to a primary pressure ratio of 9.0. This change represents a 63.5-percent increase in the range of operation for a 9.1-percent increase in diameter ratio. Secondary pressure ratios shown in figure 6 are independent of cooling-air-duct frictional characteristics because the secondary flow equals zero. The secondary pressure ratio at cut-off may therefore be taken as the over-all pressure ratio across the secondary flow system. Thus the cut-off point may be estimated from the secondary-duct inlet total pressure corresponding to various flight conditions without considering internal duct characteristics.

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Thrust Characteristics

In order to determine the effect of the ejector shroud on thrust performance, ejector jet thrust was measured simultaneously with the preceding weight-flow data and at zero secondary flow conditions. The thrust ratio was then defined as the ratio of ejector thrust F_{ej} to the previously measured thrust of the convergent primary nozzle F_j operating at the same over-all primary pressure ratio. This method, of course, does not charge either stream for inlet momentum of the air flow.

The variation of thrust ratio with over-all primary pressure ratio is shown in figures 7(a) to 7(e) and 7(f) to 7(i) for respective diameter ratios of 1.06 and 1.40. The data are presented for several constant secondary pressure ratios and for zero secondary flow conditions. In general, the thrust-ratio curves at constant secondary pressure ratio meet the zero secondary flow thrust curve at the same primary pressure ratio for which the weight-flow ratio became zero. However, for all 1.06-diameter-ratio configurations investigated (figs. 7(a) to 7(e)) several thrust ratio curves intersected and fell below the zero secondary flow thrust curve at low values of primary pressure ratio (P_p/p_0 less than 2.0). This effect occurred because at a given over-all primary pressure ratio across the ejector the effective pressure ratio across the primary nozzle was dependent upon the pressure existing within the shroud at the primary nozzle exit.

Effective primary pressure ratio approximately equals the over-all primary pressure ratio divided by the secondary pressure ratio. Therefore, at pressure ratios for which the primary nozzle was not choked, a greater thrust (because of the greater mass flow in the primary system) was produced at zero secondary flow conditions than with a finite secondary air flow and consequent higher shroud pressure. Fortunately, actual ejector installations are seldom required to operate in this low range of primary pressure ratios. A similar effect was exhibited in reference 1 for the smallest spacing ratio of each diameter ratio investigated ($S/D_p = 0.39$, $D_s/D_p = 1.21$ and 1.10) but did not occur for any 1.40-diameter-ratio configuration.

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Thrust characteristics for both the 1.06- and 1.40-diameter-ratio ejectors are similar to those discussed in reference 1. Values of thrust ratio both greater and less than 1.0 were obtained at high secondary pressure ratios, but at secondary pressure ratios below 1.0 the thrust ratio remained below 1.0 for most configurations. The 1.40-diameter-ratio ejector produced a larger thrust gain at high secondary pressure ratios and a larger thrust loss at low secondary pressure ratios than did the 1.06-diameter-ratio ejector. The smooth flat characteristics of the thrust-ratio curves in figures 7(f) to 7(h) indicate that the 1.40-diameter-ratio ejector can maintain practically a constant thrust over a wide range of primary pressure ratios if the secondary pressure ratio is relatively close to a value of 1.0. The lowest value of thrust ratio for all configurations, of course, occurred at zero secondary flow conditions (except as previously discussed for the diameter ratio of 1.06). Thus, the zero secondary flow thrust curve indicates the maximum loss (or minimum gain) in thrust that can occur for a specific operating primary pressure ratio. Losses as great as 7 percent and 29.5 percent at primary pressure ratios less than 3.5, and gains of 2.4 percent and 1.4 percent at the primary pressure ratio of 10, were obtained for the respective diameter ratios of 1.06 and 1.40 when compared with the thrust of the convergent primary nozzle at the same conditions. However, when the ejector is operating with secondary flow, the thrust losses will be decreased and the thrust gains will be increased by an amount dependent on the magnitude of secondary air flow.

Effect of Spacing Ratio on Thrust

The variation of thrust ratio with spacing ratio is shown in figure 8 (cross plots of preceding thrust data) for primary pressure ratios of 2.0, 3.5, and 9.0. Changes in spacing ratio at constant secondary pressure ratio had an appreciable effect on thrust ratio for both diameter ratios investigated. Thus, the spacing ratio is a factor to be considered when an ejector configuration for maximum thrust is selected.

Comparison of pumping and thrust characteristics for the 1.06-diameter-ratio ejector (figs. 4(a) to 4(c) and 8(a) to 8(c)) indicated that the spacing ratio corresponding to a region of maximum thrust was either less than or greater than the spacing ratio for maximum pumping, depending upon the operating conditions. The same comparison for the 1.40-diameter-ratio ejector, however, indicated that the spacing ratio for maximum thrust was generally less than that for maximum pumping, as was also indicated in reference 1 for diameter ratios of 1.21 and 1.10.

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Effect of Diameter Ratio on Thrust

Gross ejector thrust ratio is presented as a function of diameter ratio in figure 9 for several values of constant spacing ratio, primary pressure ratio, and secondary pressure ratio as cross-plotted from reference 1 and data contained herein. These plots exhibit thrust characteristics similar to the pumping characteristics previously described and shown in figure 5. As diameter ratio was increased, there was, in general, a continuous rise in gross thrust ratio for values of secondary pressure ratio greater than 1.0; whereas for secondary pressure ratios less than 1.0, the thrust ratio maximized, or in some cases, continuously decreased with increased diameter ratio.

Application of Data

The comparisons made herein are based on conical-ejector characteristics alone as determined with an unheated primary jet. As pointed out in reference 1, a final choice of ejector geometry must be based on the cooling-air supply duct characteristics and flight plan of a specific aircraft after the values of weight-flow ratio are corrected for temperature ratio as described in reference 2. This correction is only approximate, but until more complete high-temperature data are available it must be assumed that performance of full-scale ejectors operating at temperature ratios greater than 1.0 may be approximated by cold-model ejector data corrected to the desired temperature ratio.

CONCLUDING REMARKS

The experimental data contained herein showing pumping and thrust characteristics of nine conical cooling-air ejectors indicated that the pumping range and amount of cooling-air flow obtained with the 1.06-diameter-ratio ejector was relatively small as compared with that of the 1.40-diameter-ratio ejector. Optimum pumping performance for the 1.06-diameter-ratio ejector (even though the amount of cooling air is low) can be approximated over a range of flight conditions with a fixed spacing ratio. In contrast, the 1.40-diameter-ratio ejector with a fixed spacing ratio that can pump adequate cooling air at one flight condition may pump an insufficient amount at another condition. The limiting primary pressure ratio below which an ejector can operate at a specific secondary pressure ratio (cut-off point) may be estimated for various flight conditions from data contained herein.

Comparison of pumping and thrust characteristics for the 1.06-diameter-ratio ejector indicated that maximum thrust was attained at spacing ratios either greater or less than the spacing ratio for maximum pumping, depending upon the operating conditions. The same comparison for the 1.40-diameter-ratio ejector indicated the spacing ratio for maximum thrust was less than for maximum pumping. At the same spacing ratio, primary pressure ratio, and secondary pressure ratio, the large-diameter-ratio ejector produced greater gains in gross thrust at secondary pressure ratios above 1.0 and greater losses in gross thrust at secondary pressure ratios below 1.0 than did the small-diameter-ratio ejector. Thrust losses as great as 7 percent and 29.5 percent of convergent nozzle thrust occurred for respective diameter ratios of 1.06 and 1.40 at zero secondary flow conditions and the extremely low secondary pressure ratios encountered.

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1. Greathouse, W. K., and Hollister, D. P.: Preliminary Air-Flow and Thrust Calibration of Several Conical Cooling-Air Ejectors With a Primary to Secondary Temperature Ratio of 1.0. I - Diameter Ratios of 1.21 and 1.10. NACA RM E52E21, 1952.

2. Wilsted, H. D., Huddleston, S. C., and Ellis, C. W.: Effect of Temperature on Performance of Several Ejector Configurations. NACA RM E9E16, 1949.

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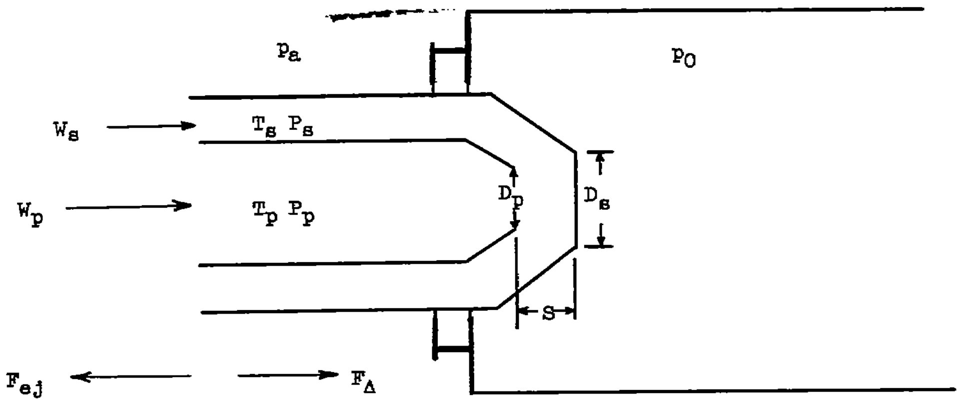

D_p	exit diameter of primary nozzle
D_s	exit diameter of secondary shroud
F_{ej}	gross ejector thrust
F_j	gross thrust of primary nozzle without shroud
F_Δ	pressure-area force acting on ejector = $(p_a - p_0) \times$ constant
P_p	total primary pressure
P_s	total secondary pressure
p_a	atmospheric pressure
p_0	ambient or exhaust pressure
S	spacing, distance from primary exit to shroud exit
T_p	total primary temperature, $^{\circ}R$
T_s	total secondary temperature, $^{\circ}R$
W_p	primary weight flow, lb/sec
W_s	secondary weight flow, lb/sec
D_s/D_p	diameter ratio
F_{ej}/F_j	thrust ratio
P_p/p_0	primary pressure ratio
P_s/p_0	secondary pressure ratio
S/D_p	spacing ratio
$\sqrt{T_p/T_s}$	weight-flow correction factor - cold data to hot data
W_s/W_p	weight-flow ratio

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Figure 1. - Nomenclature for ejector investigation.

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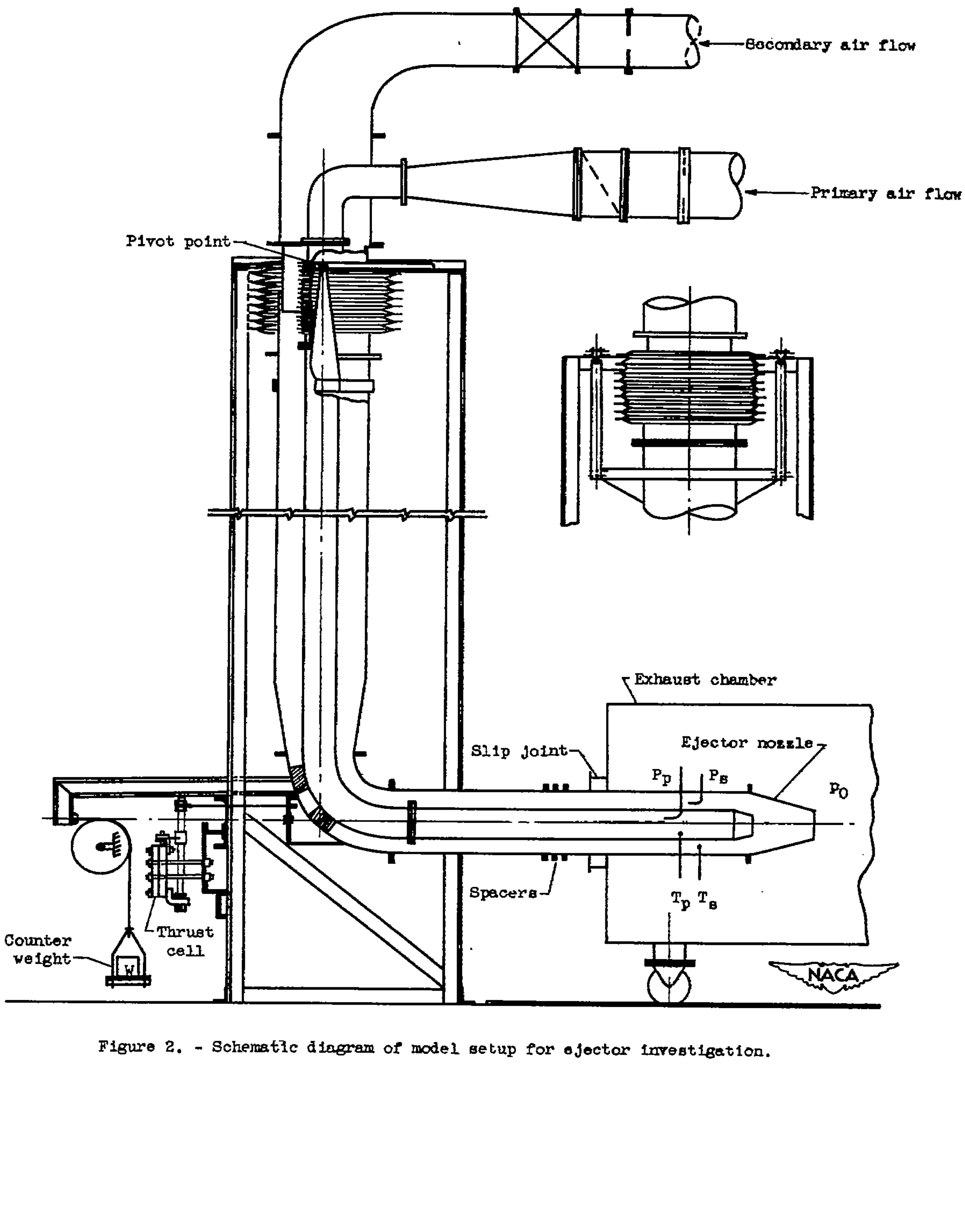

Figure 2. - Schematic diagram of model setup for ejector investigation.

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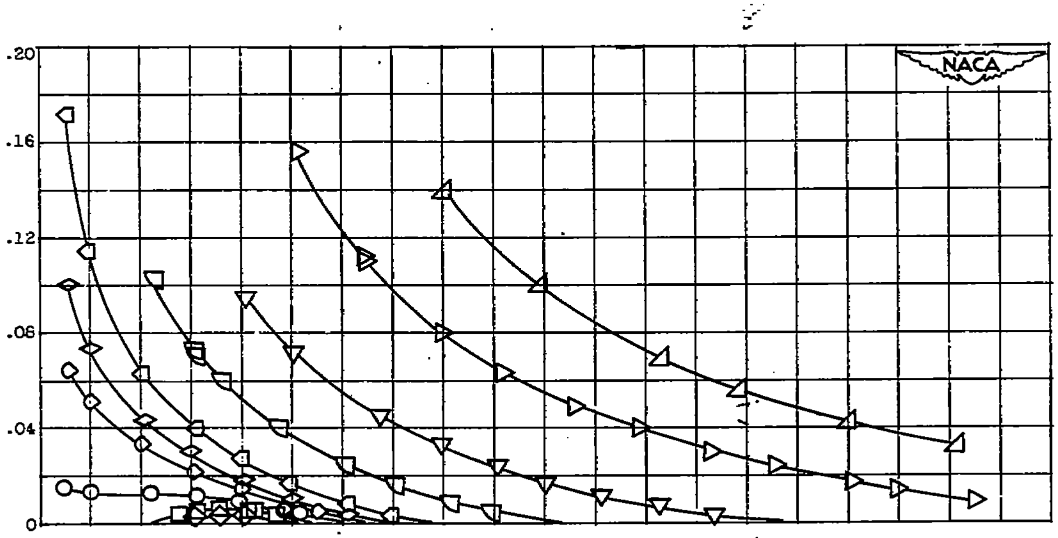
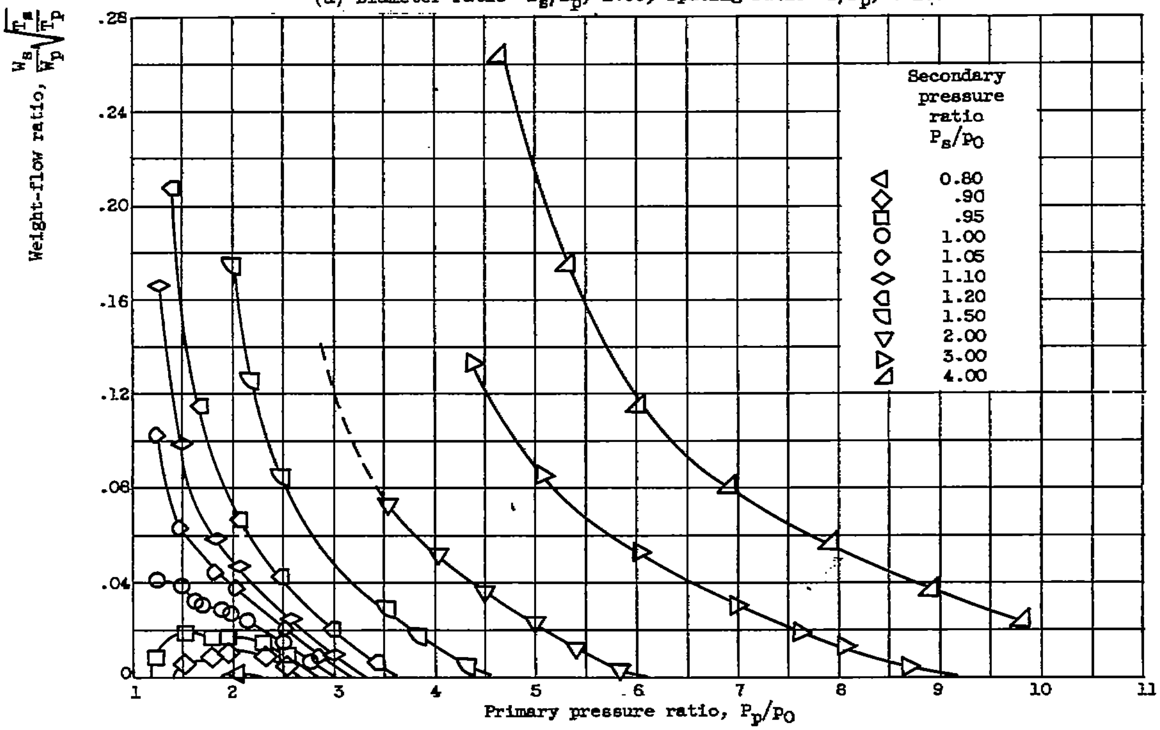


(a) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.165.



(b) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.386.

Figure 3. - Effect of primary and secondary pressure ratios on ejector weight-flow ratio.

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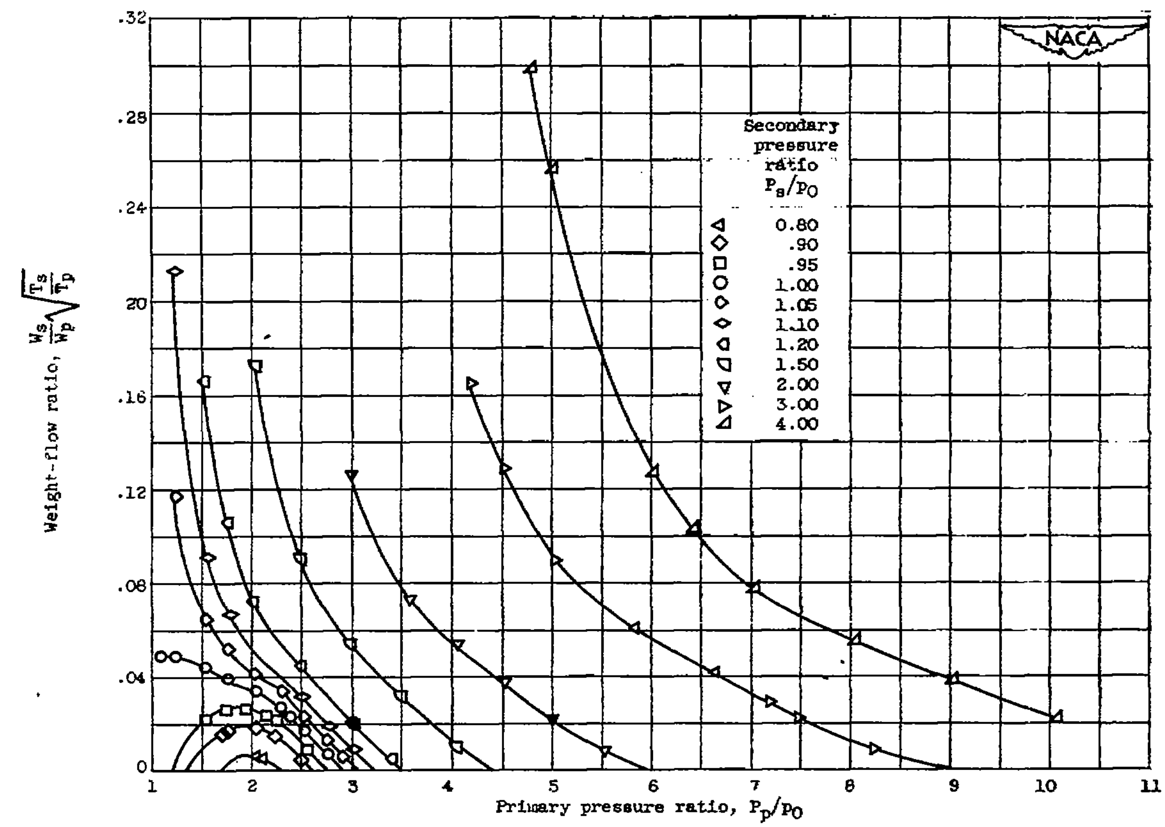

(c) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.572.

Figure 3. - Continued. Effect of primary and secondary pressure ratios on ejector weight-flow ratio.

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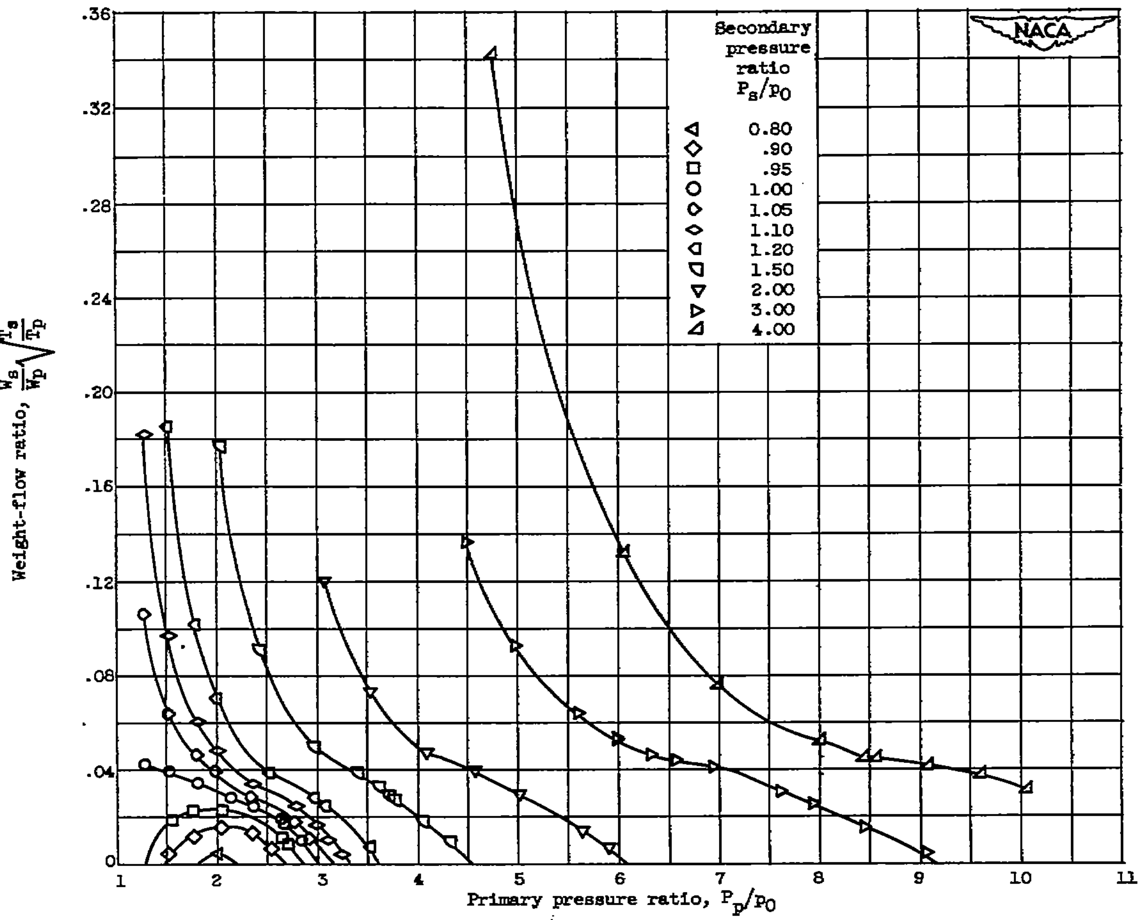

(d) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.776.

Figure 3. - Continued. Effect of primary and secondary pressure ratios on ejector weight-flow ratio.

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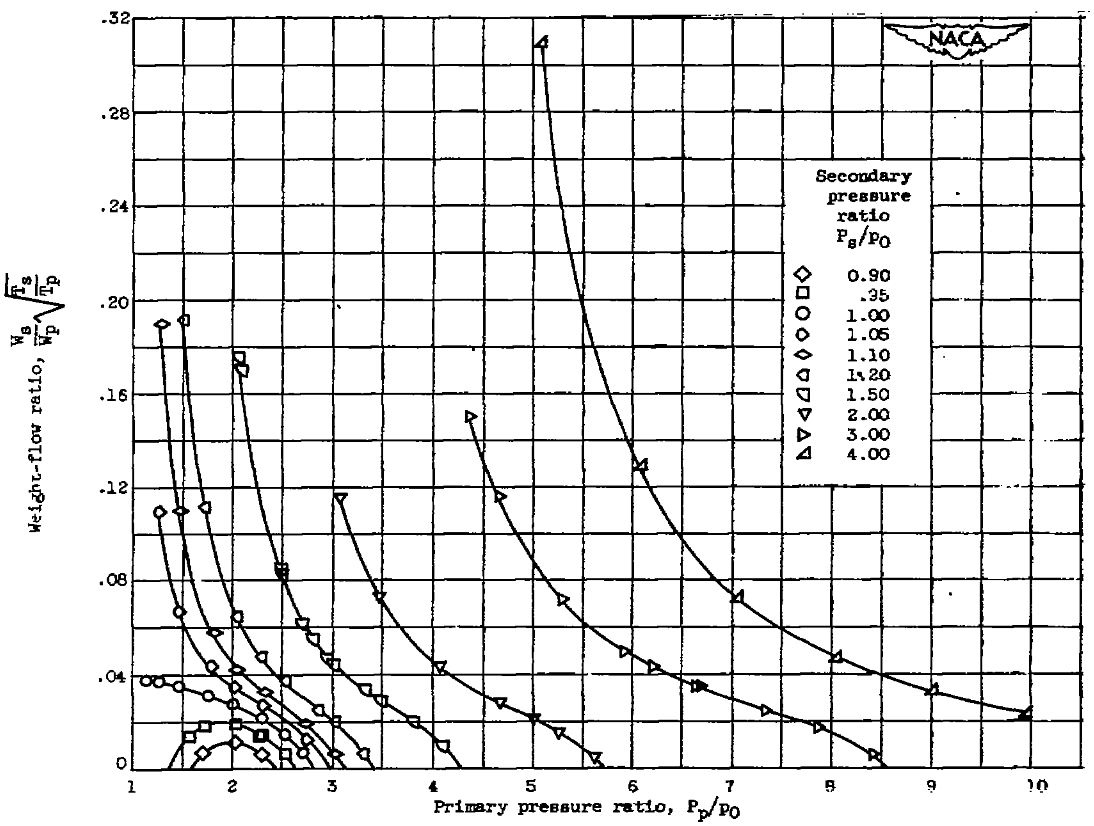

(e) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.977.

Figure 5. - Continued. Effect of primary and secondary pressure ratios on ejector weight-flow ratio.

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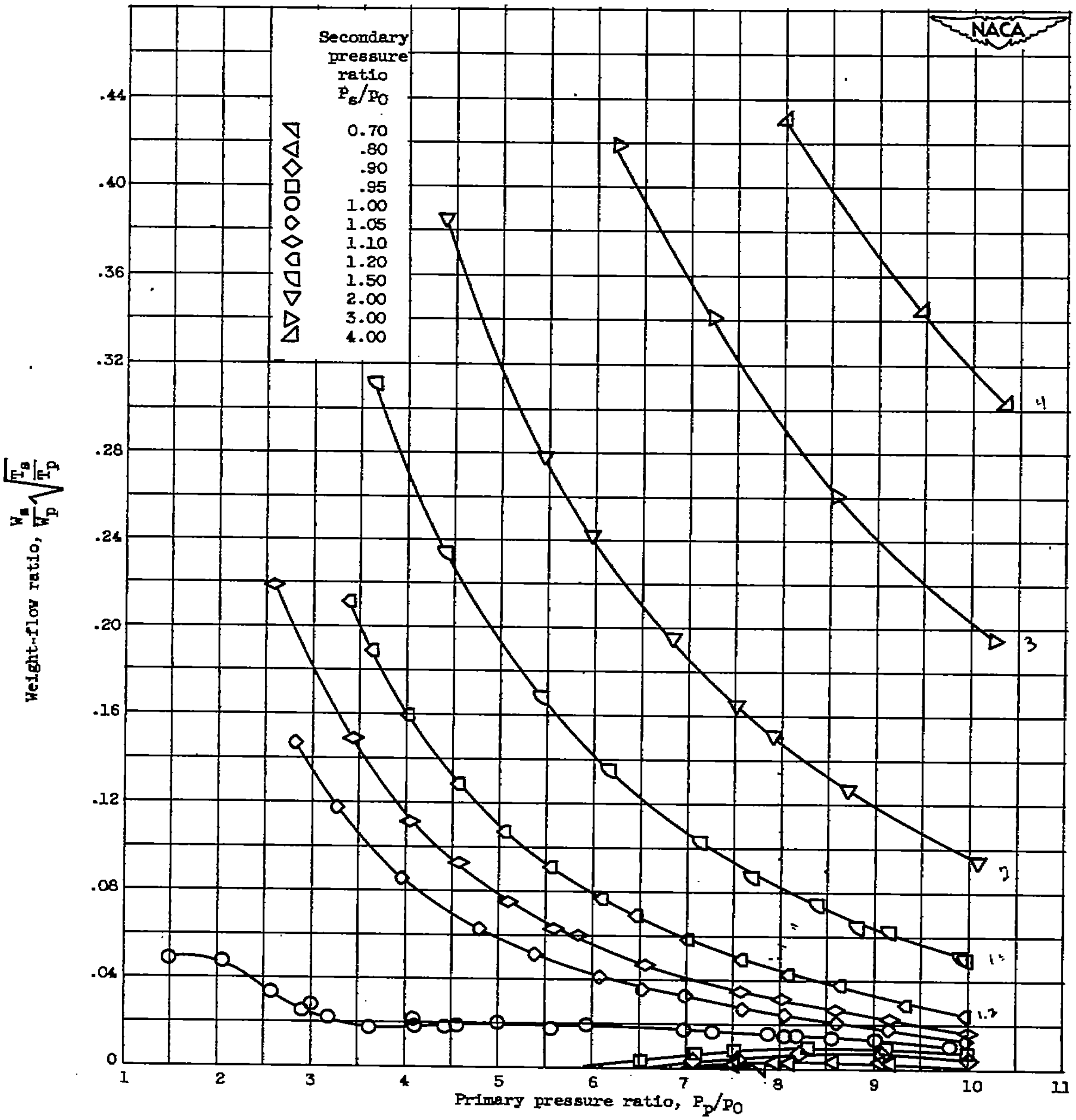

(f) Diameter ratio D_s/D_p, 1.40; spacing ratio S/D_p, 0.37.

Figure 3. - Continued. Effect of primary and secondary pressure ratios on ejector weight-flow ratio.

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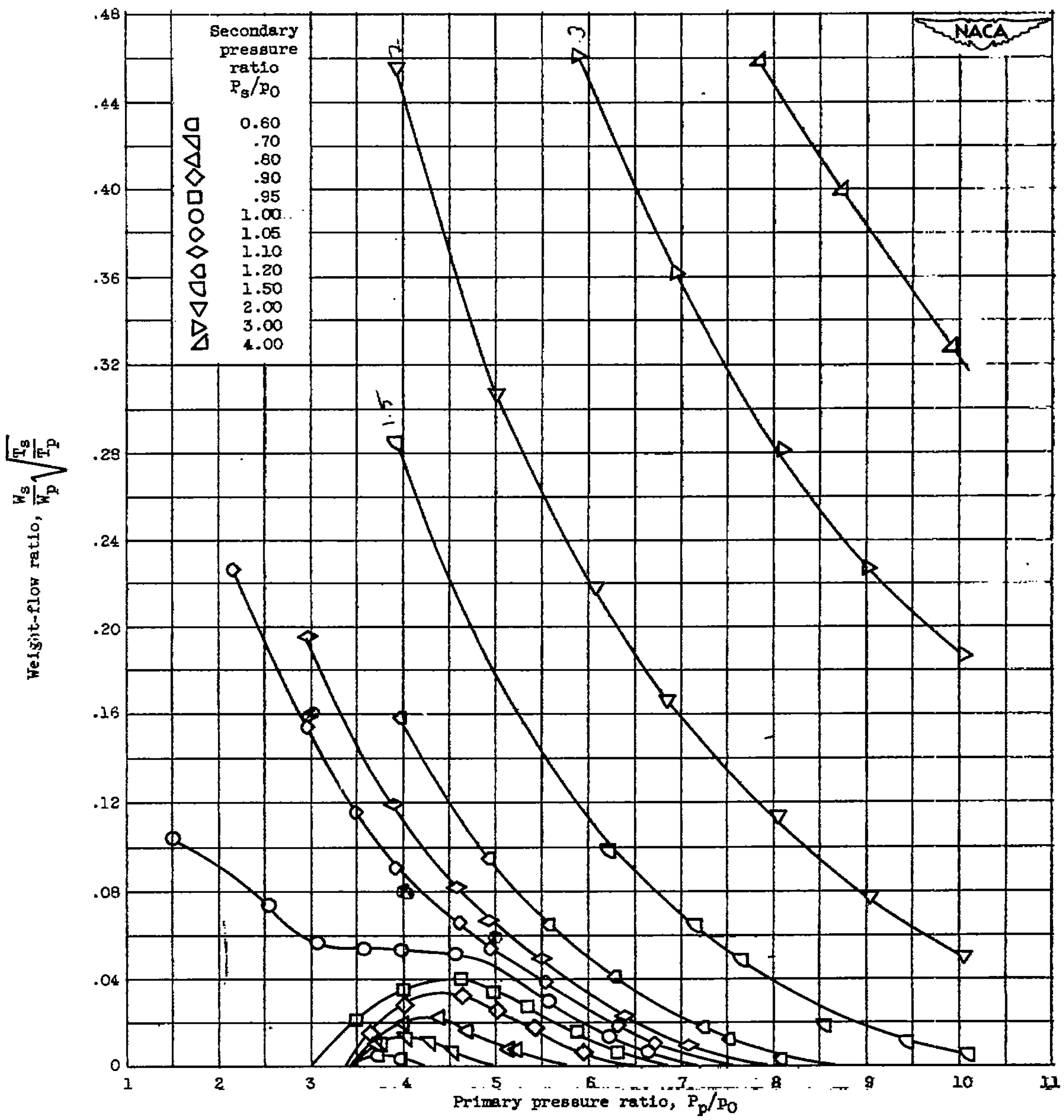

(g) Diameter ratio D_s/D_p, 1.40; spacing ratio S/D_p, 0.803.

Figure 3. - Continued. Effect of primary and secondary pressure ratios on ejector weight-flow ratio.

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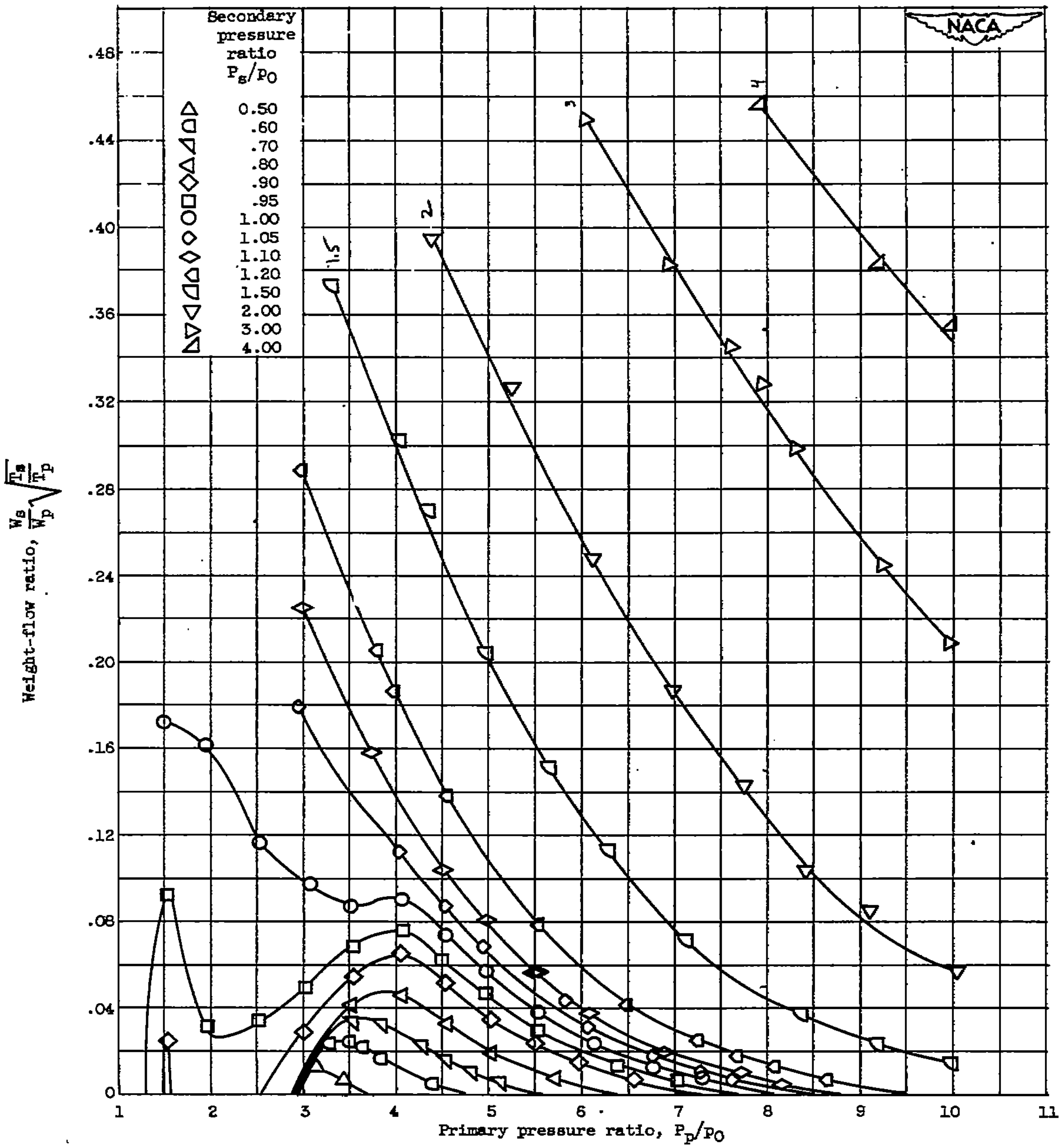
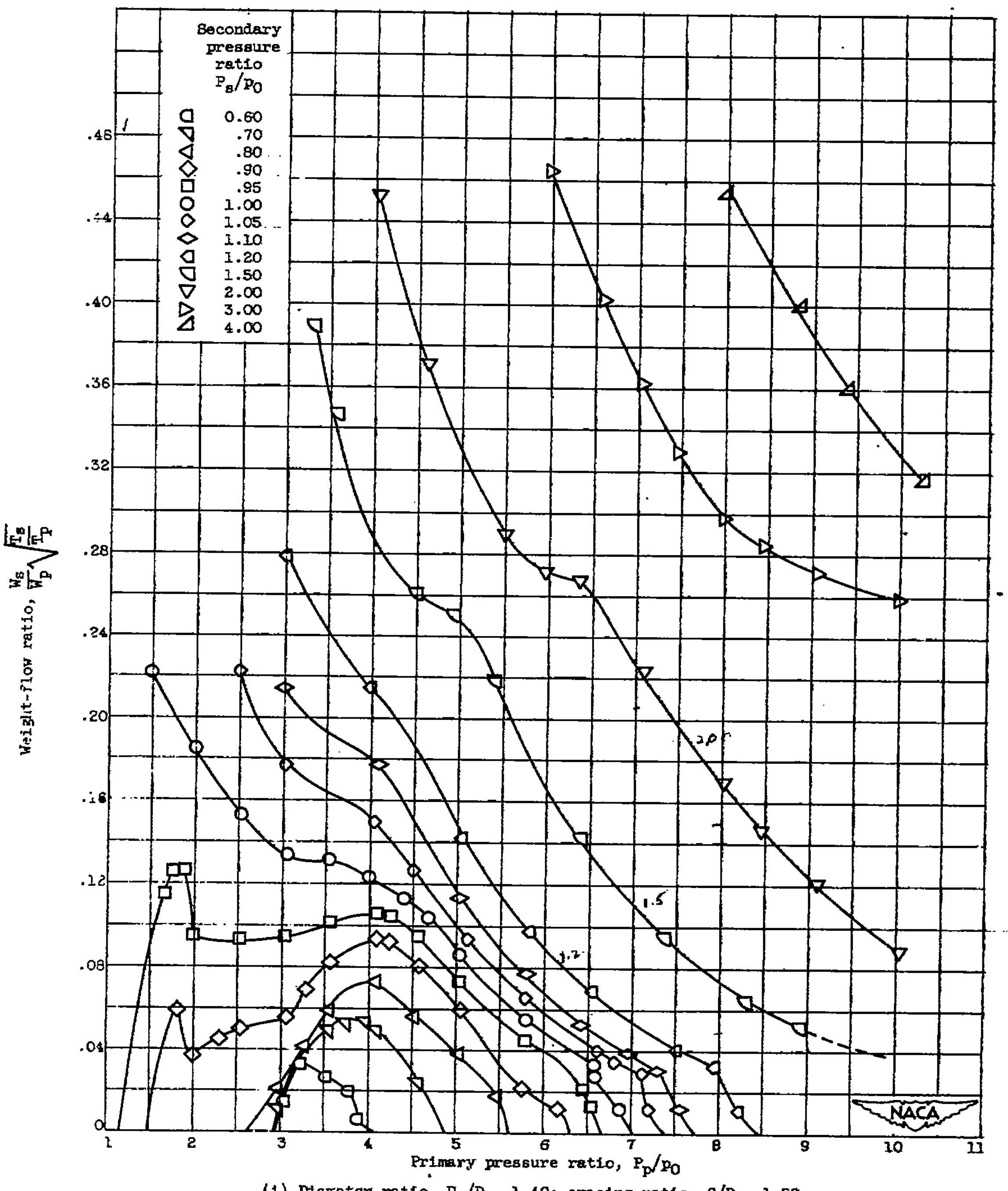


(h) Diameter ratio D_s/D_p, 1.40; spacing ratio S/D_p, 1.19.

Figure 3. - Continued. Effect of primary and secondary pressure ratios on ejector weight-flow ratio.



(i) Diameter ratio D_s/D_p, 1.40; spacing ratio S/D_p, 1.59.

Figure 3. - Concluded. Effect of primary and secondary pressure ratios on ejector weight-flow ratio.

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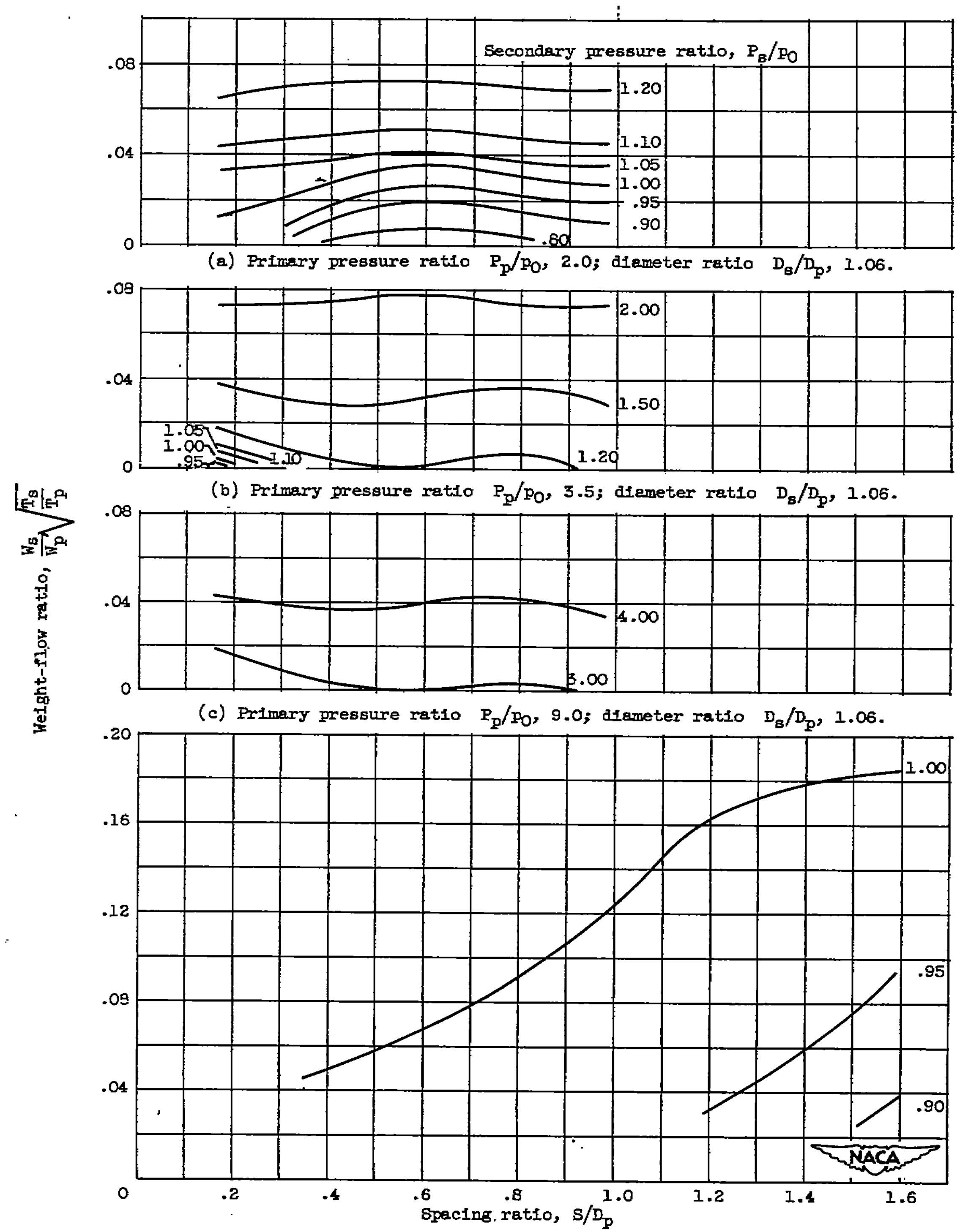

(a) Primary pressure ratio P_p/p_0, 2.0; diameter ratio D_s/D_p, 1.06.

(b) Primary pressure ratio P_p/p_0, 3.5; diameter ratio D_s/D_p, 1.06.

(c) Primary pressure ratio P_p/p_0, 9.0; diameter ratio D_s/D_p, 1.06.

(d) Primary pressure ratio P_p/p_0, 2.0; diameter ratio D_s/D_p, 1.40.

Figure 4. - Effect of spacing ratio on ejector weight-flow ratio.

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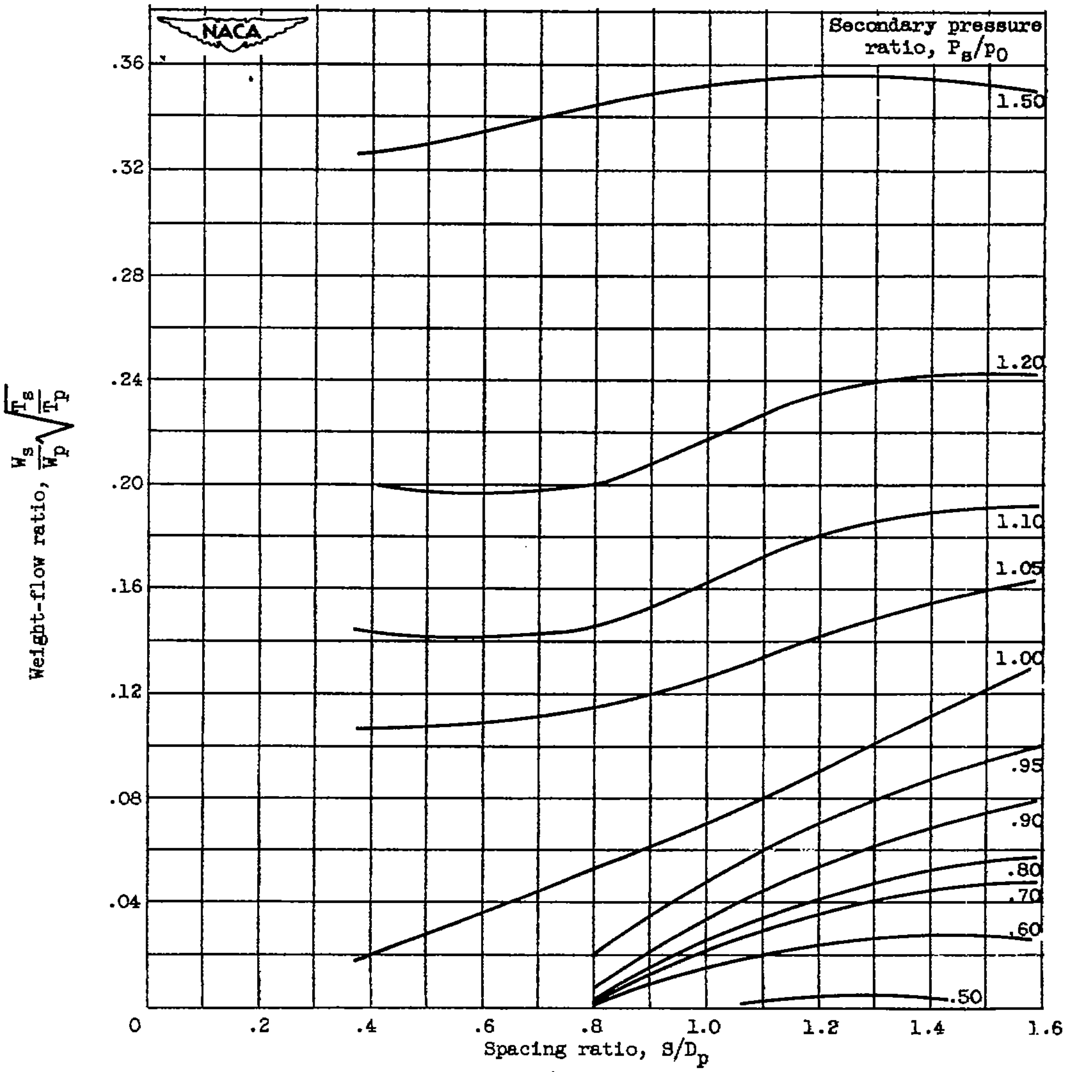

(e) Primary pressure ratio P_p/p_0, 3.5; diameter ratio D_s/D_p, 1.40.

Figure 4. - Continued. Effect of spacing ratio on ejector weight-flow ratio.

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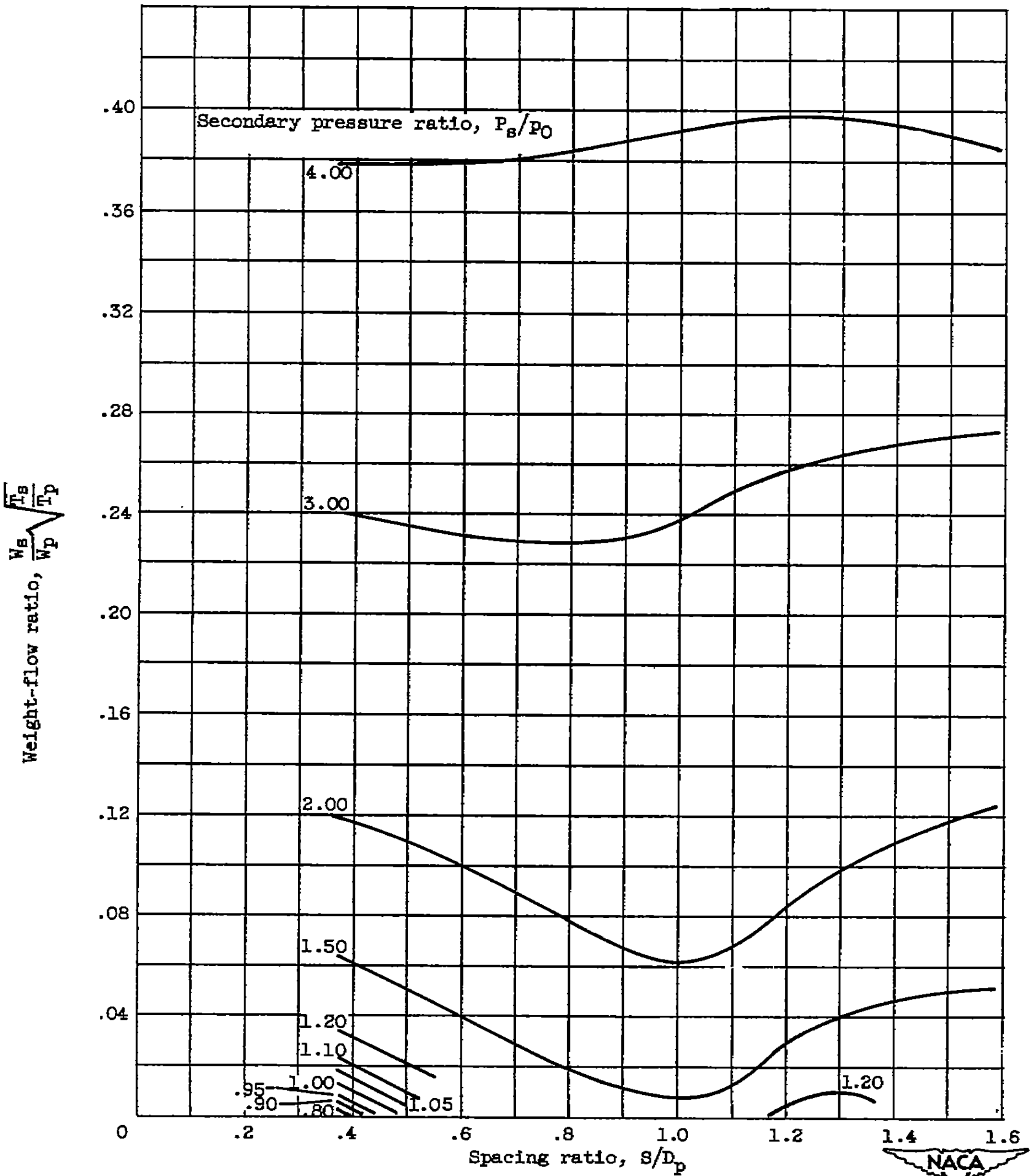

(f) Primary pressure ratio P_p/p_0, 9.0; diameter ratio D_s/D_p, 1.40.

Figure 4. - Concluded. Effect of spacing ratio on ejector weight-flow ratio.

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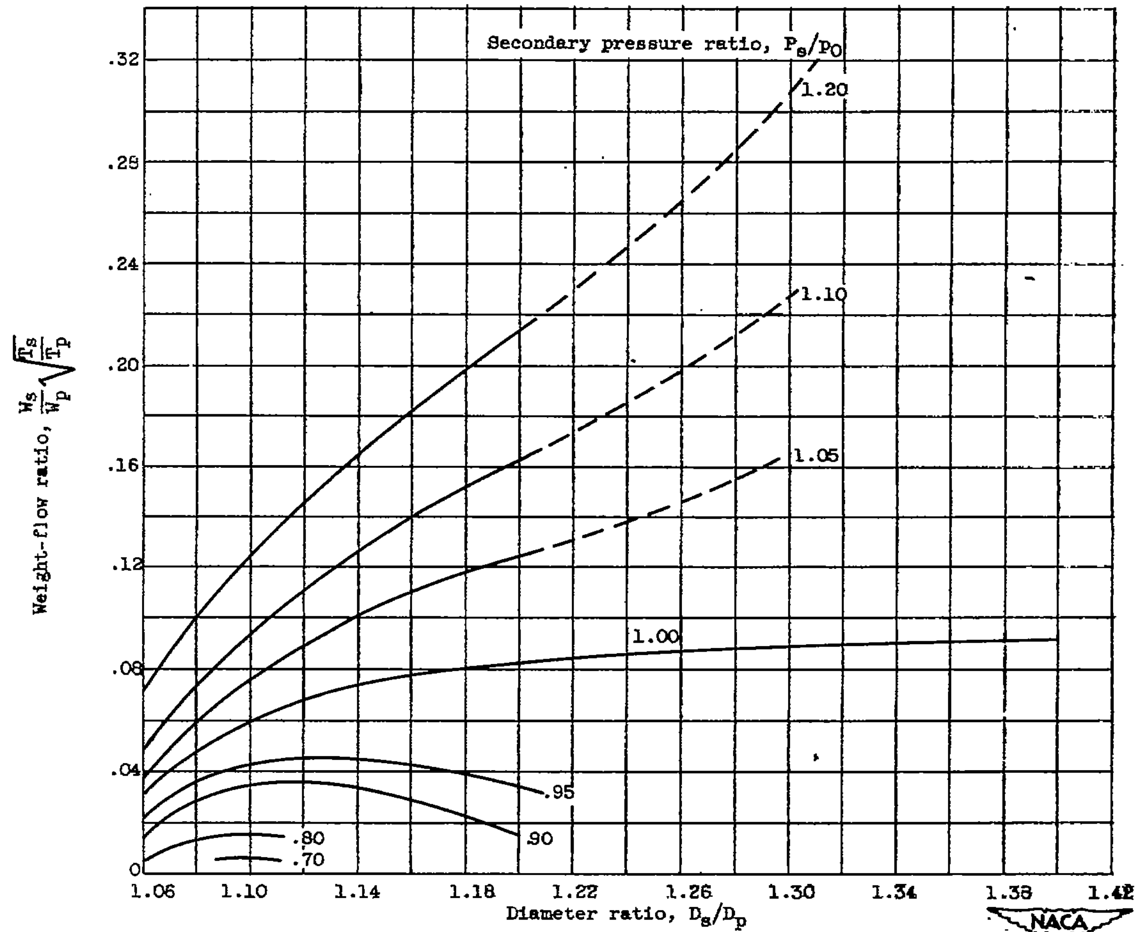

(a) Spacing ratio S/D_p, 0.80; primary ~~pressure~~ ratio P_p/p_0, 2.0.

Figure 5. - Effect of diameter ratio on ejector weight-flow ratio.

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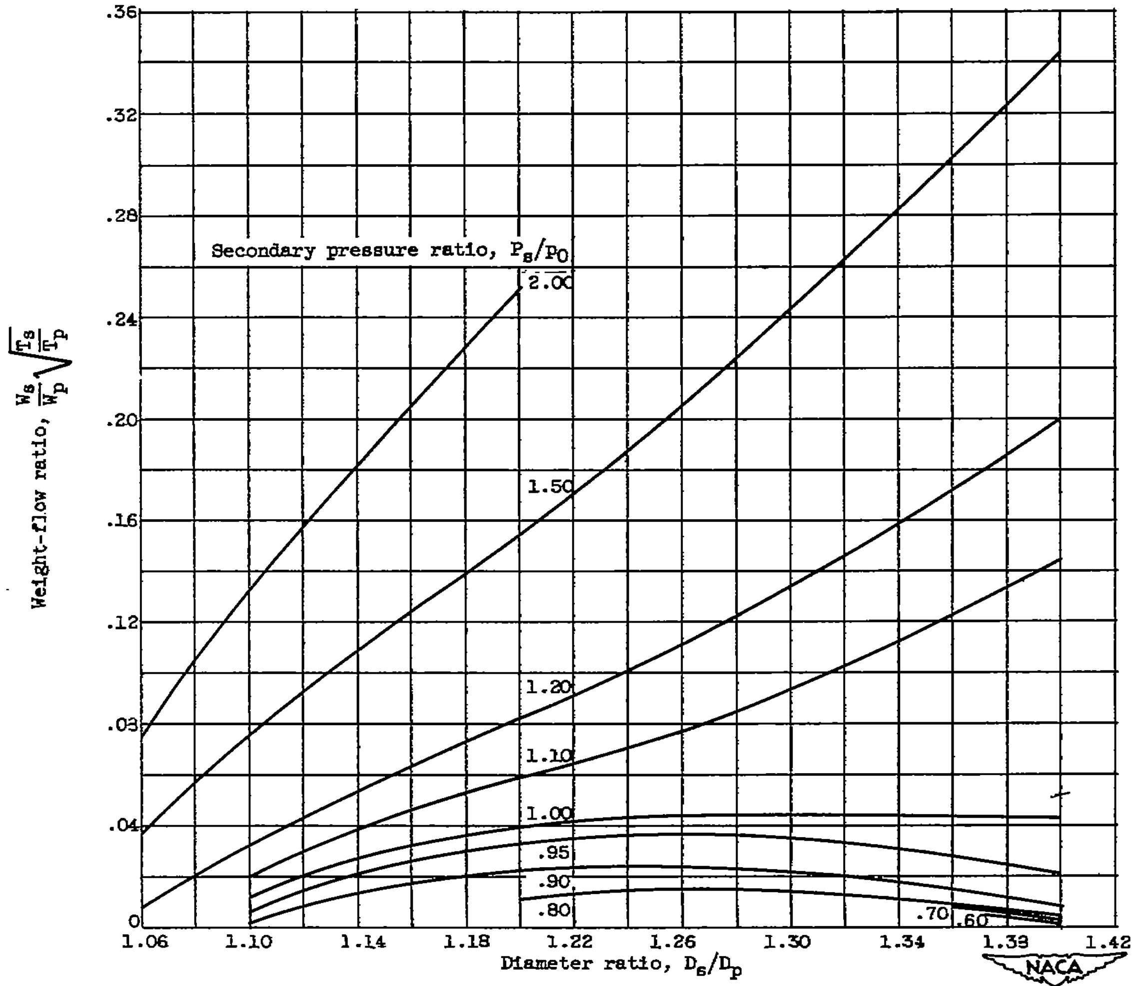

(b) Spacing ratio S/D_p, 0.80; primary pressure ratio P_p/p_0, 3.5.

Figure 5. - Continued. Effect of diameter ratio on ejector weight-flow ratio.

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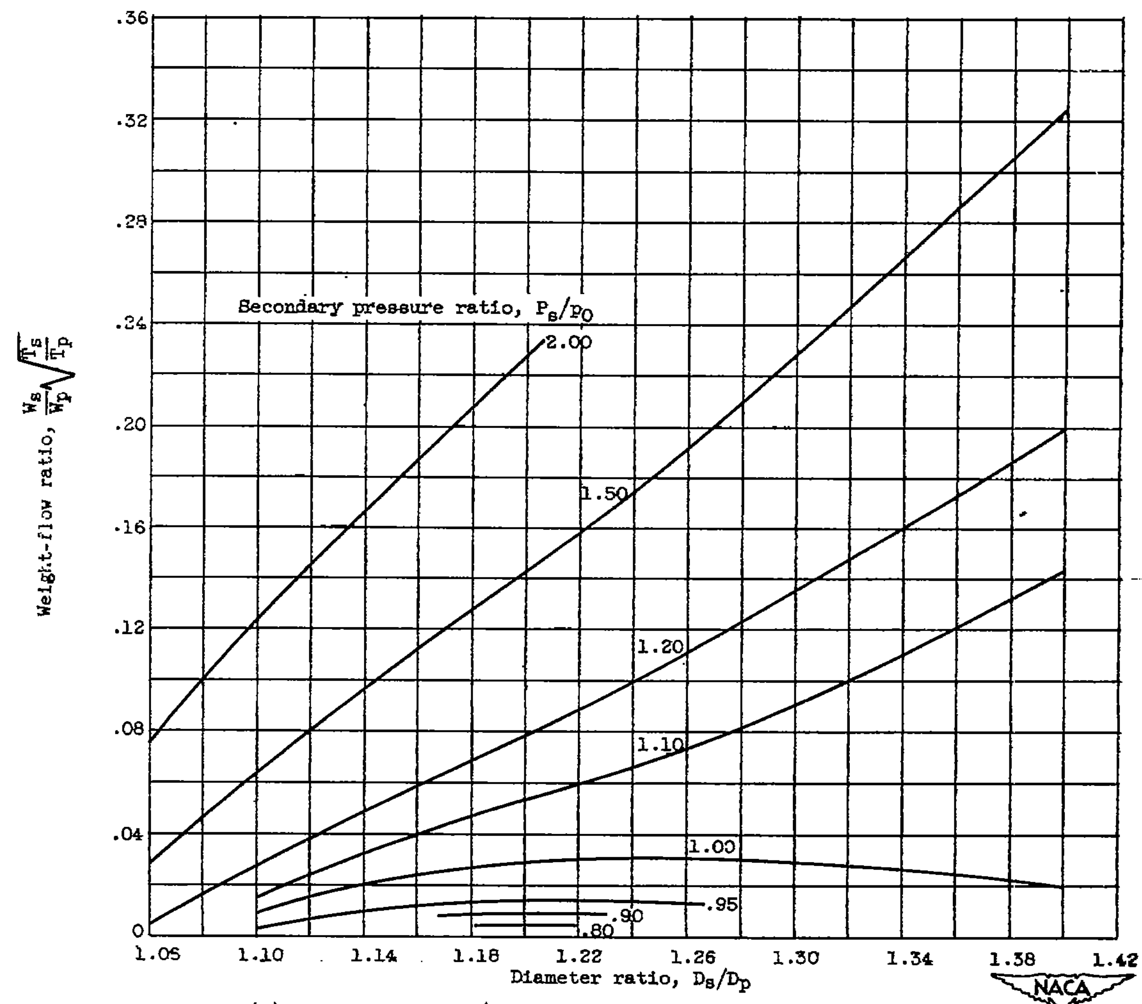

(c) Spacing ratio S/D_p, 0.40; primary pressure ratio P_p/p_0, 3.5.

Figure 5. - Concluded. Effect of diameter ratio on ejector weight-flow ratio.

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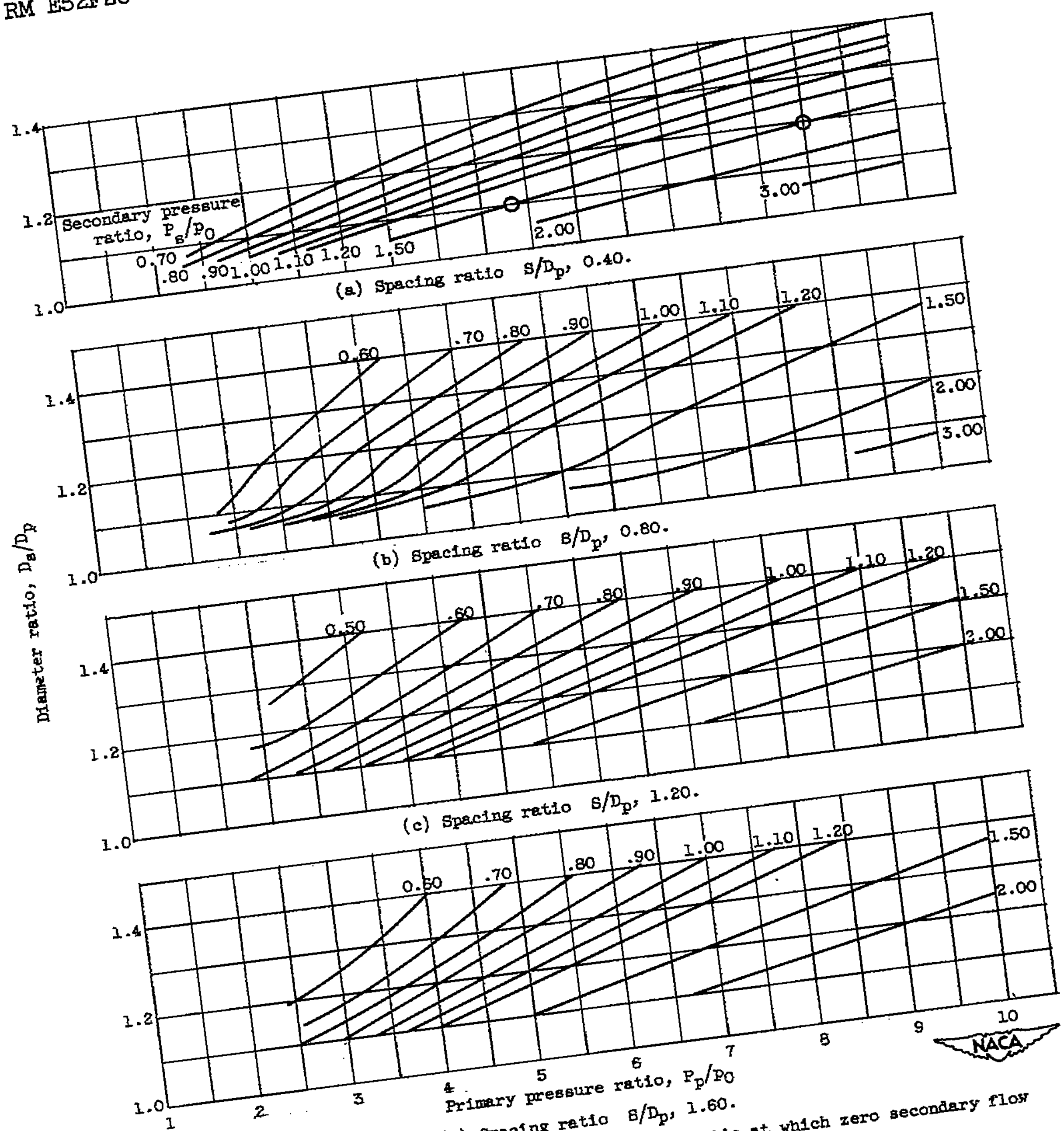

(a) Spacing ratio S/D_p, 0.40.

(b) Spacing ratio S/D_p, 0.80.

(c) Spacing ratio S/D_p, 1.20.

(d) Spacing ratio S/D_p, 1.60.

Figure 6. - Effect of diameter ratio on primary pressure ratio at which zero secondary flow occurred (cut-off point).

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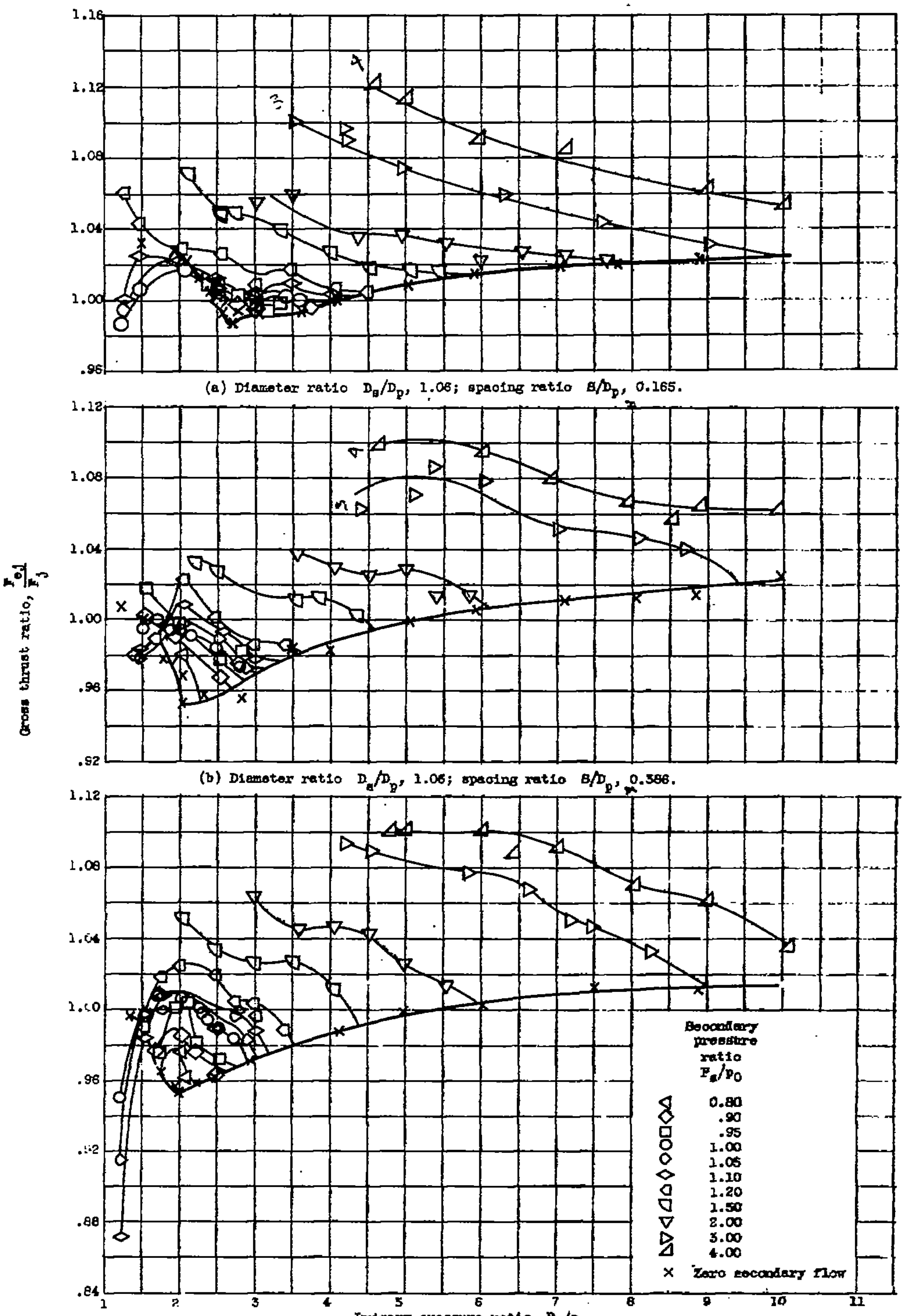

(a) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.165.

(b) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.386.

(c) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.572.

Figure 7. - Effect of primary and secondary pressure ratio on ejector gross thrust ratio.

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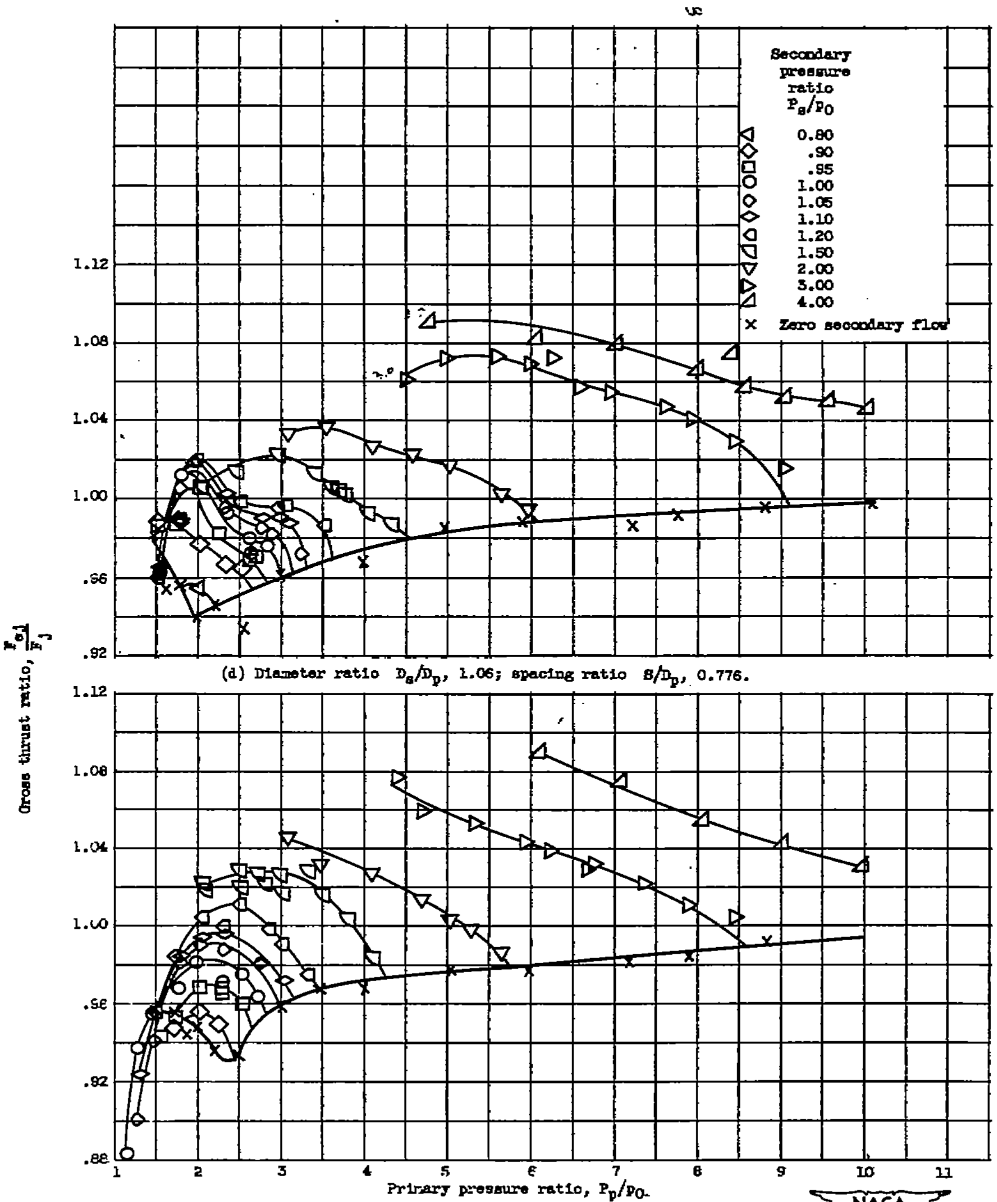
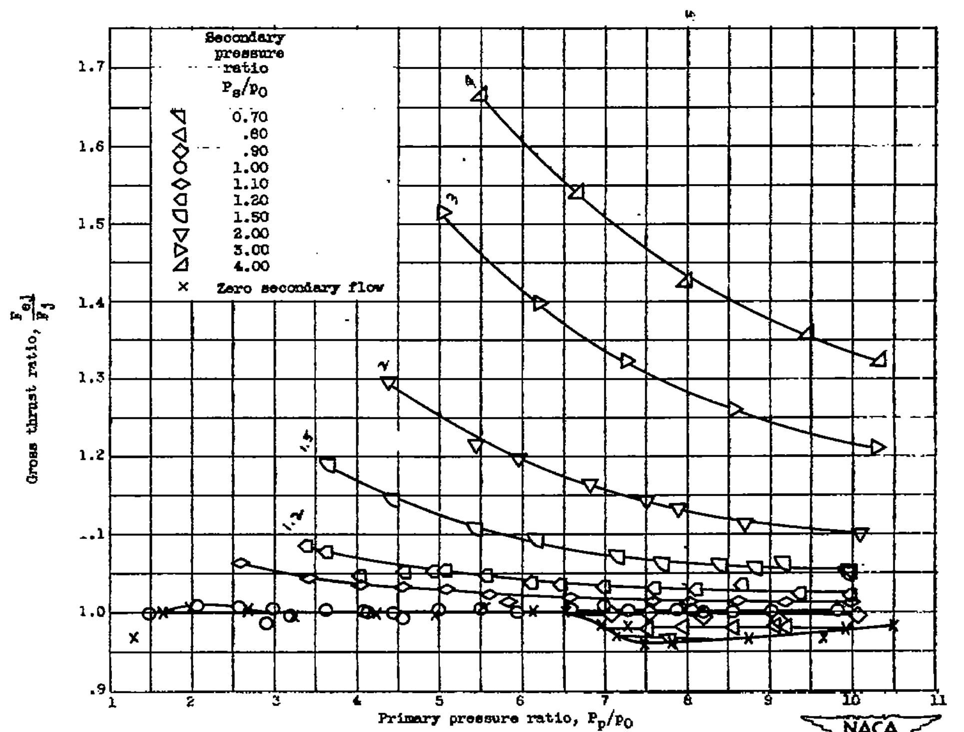


(d) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.776.

(e) Diameter ratio D_s/D_p, 1.06; spacing ratio S/D_p, 0.977.

Figure 7. - Continued. Effect of primary and secondary pressure ratio on ejector gross thrust ratio.

2623

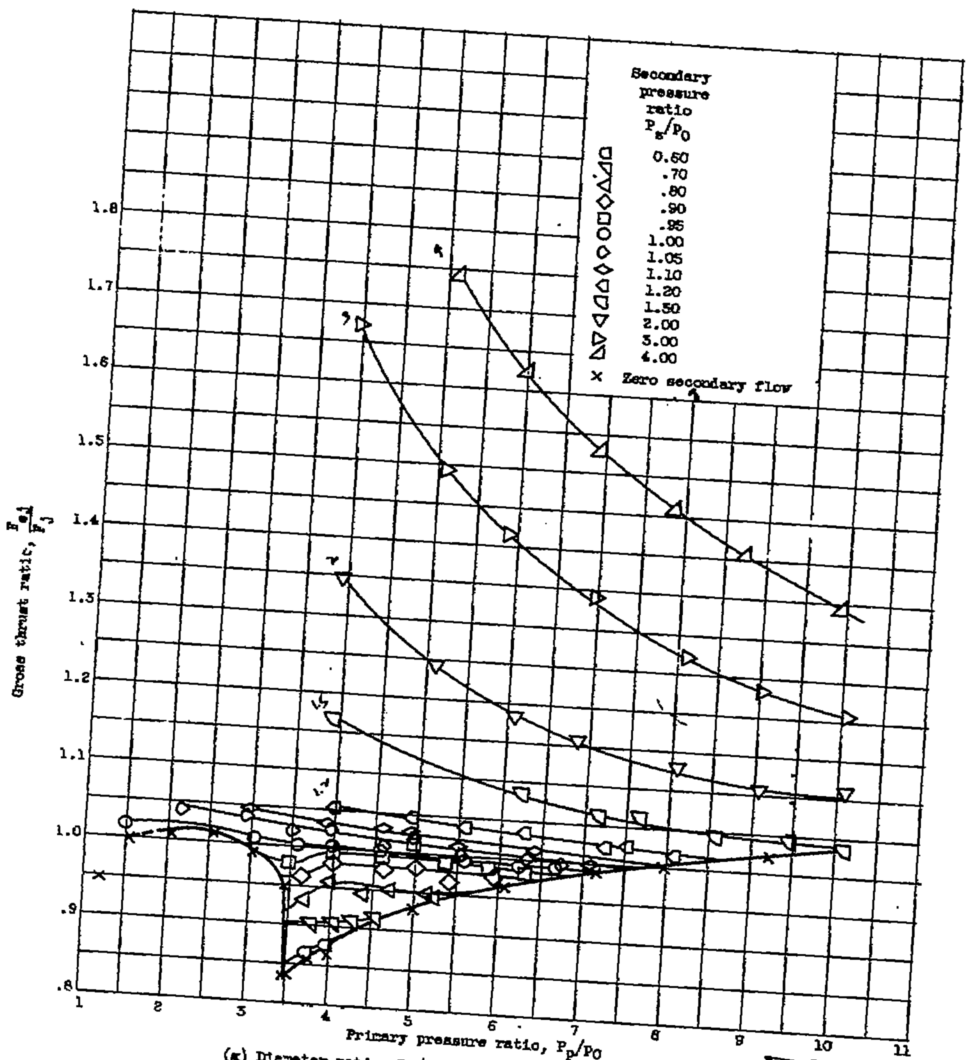


(f) Diameter ratio D_s/D_p, 1.40; spacing ratio S/D_p, 0.37.

Figure 7. - Continued. Effect of primary and secondary pressure ratio on ejector gross thrust ratio.

[redacted]

2623



(g) Diameter ratio D_s/D_p, 1.40; spacing ratio S/D_p, 0.803.

Figure 7. - Continued. Effect of primary and secondary pressure ratio on ejector gross thrust ratio.

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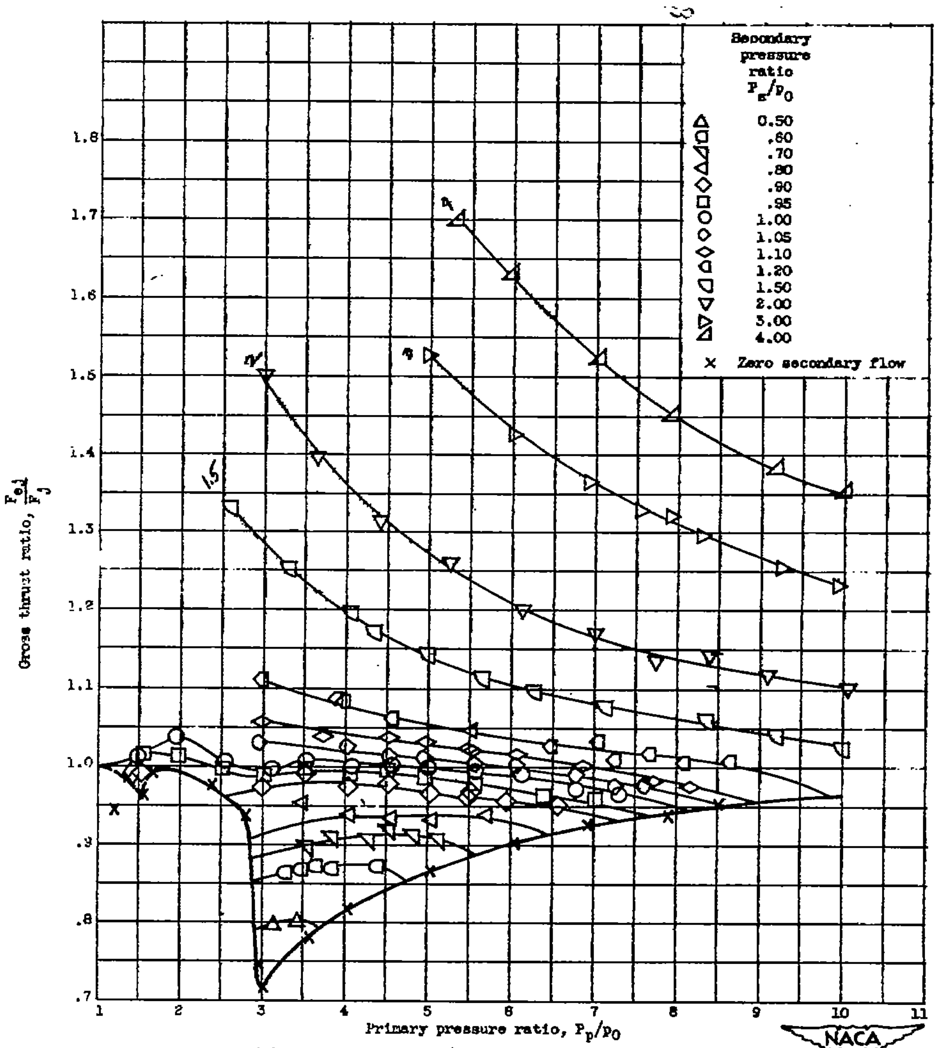
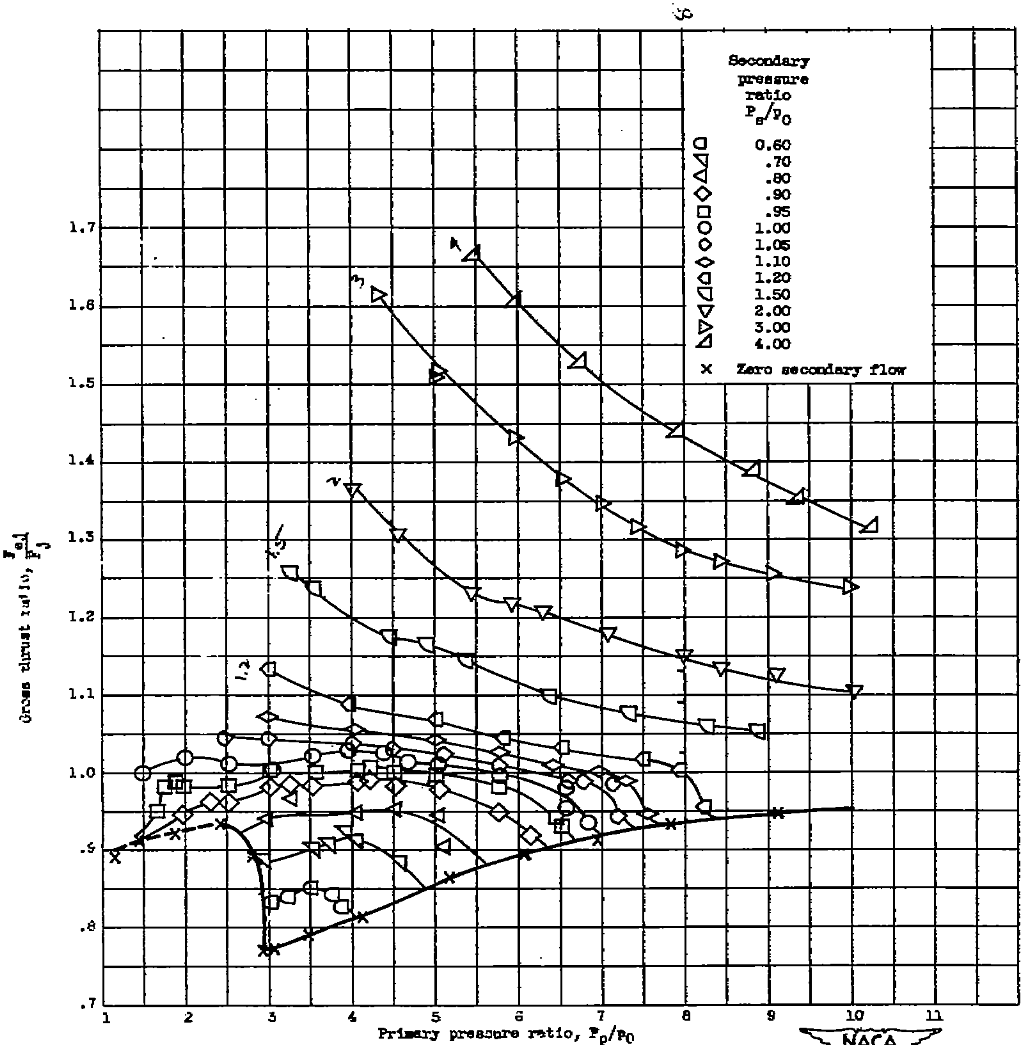
2623



(h) Diameter ratio D_s/D_p, 1.40; spacing ratio S/D_p, 1.19.

Figure 7. - Continued. Effect of primary and secondary pressure ratio on ejector gross thrust ratio.

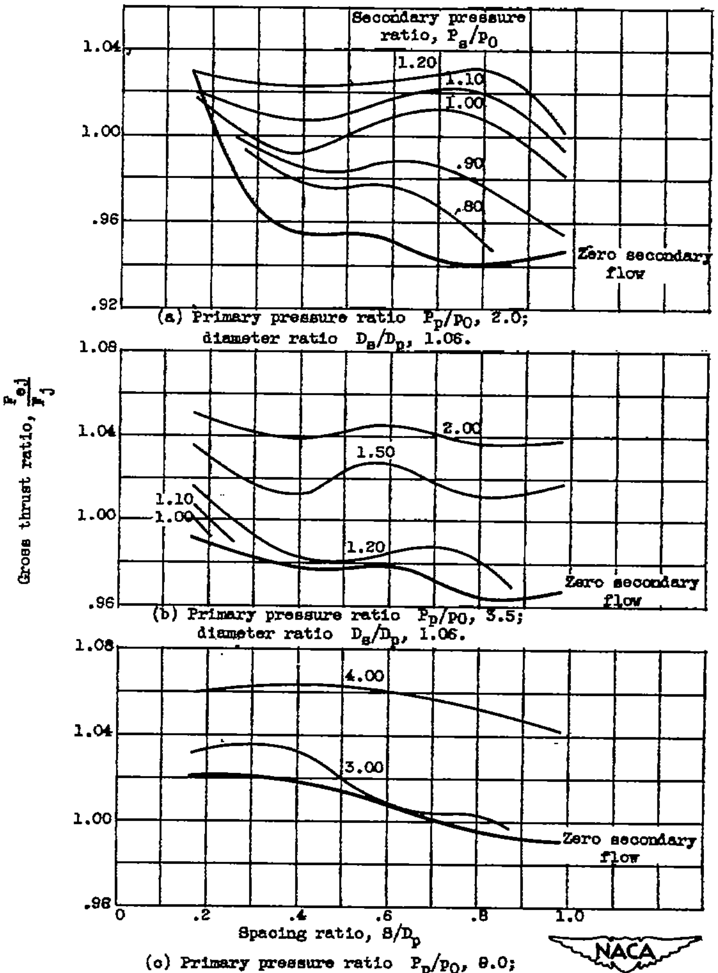
2623



(i) Diameter ratio D_s/D_p, 1.40; spacing ratio S/D_p, 1.59.

Figure 7. - Concluded. Effect of primary and secondary pressure ratio on ejector gross thrust ratio.

2623

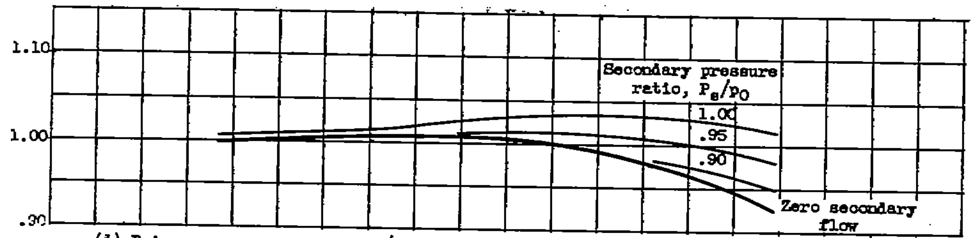


(a) Primary pressure ratio P_p/p_0, 2.0; diameter ratio D_s/D_p, 1.06.

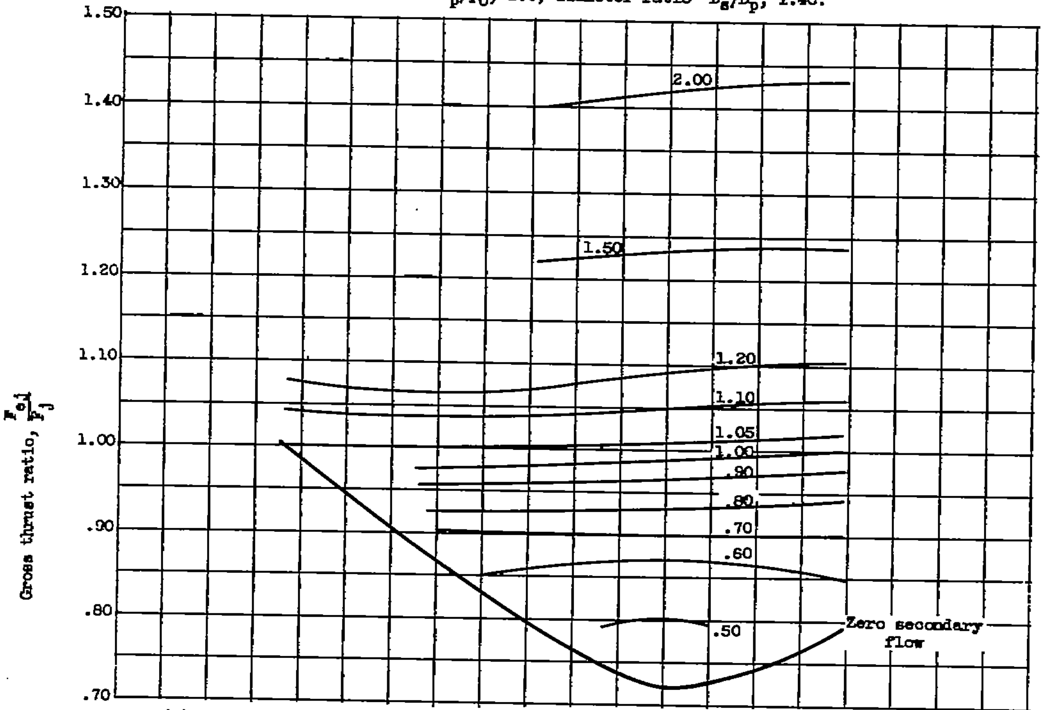
(b) Primary pressure ratio P_p/p_0, 3.5; diameter ratio D_s/D_p, 1.06.

(c) Primary pressure ratio P_p/p_0, 8.0; diameter ratio D_s/D_p, 1.06.

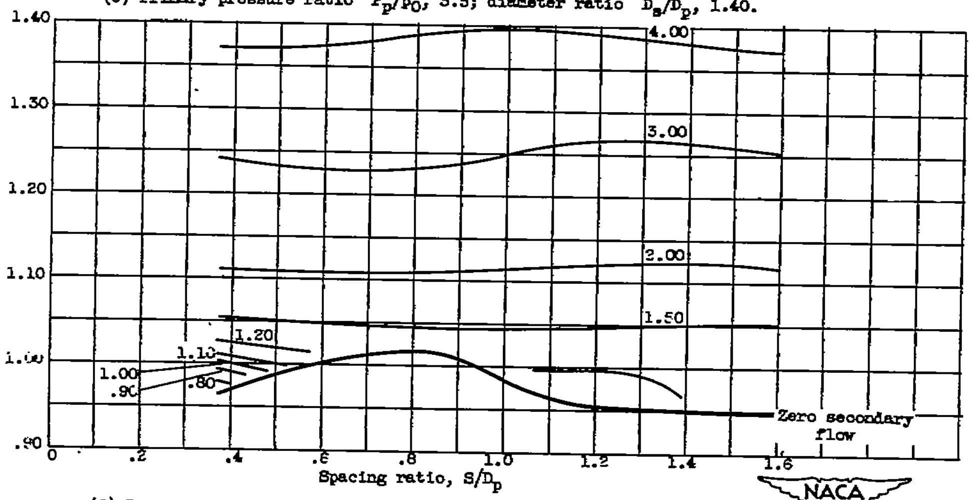
Figure 8. - Effect of spacing ratio on ejector gross thrust ratio.



(d) Primary pressure ratio P_p/p_0, 2.0; diameter ratio D_s/D_p, 1.40.



(e) Primary pressure ratio P_p/p_0, 3.5; diameter ratio D_s/D_p, 1.40.



(f) Primary pressure ratio P_p/p_0, 9.0; diameter ratio D_s/D_p, 1.40.

Figure 8. - Concluded. Effect of spacing ratio on ejector gross thrust ratio.

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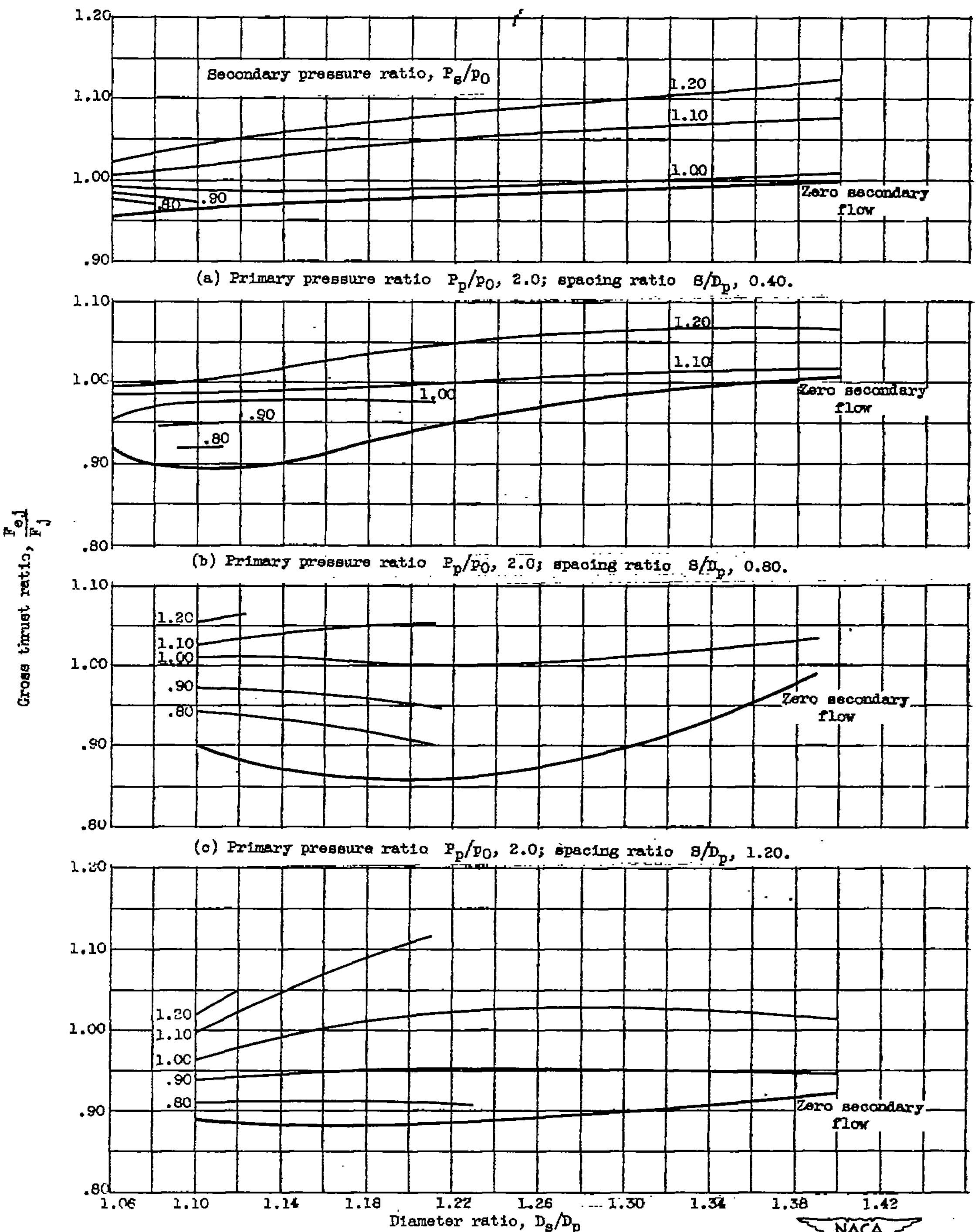
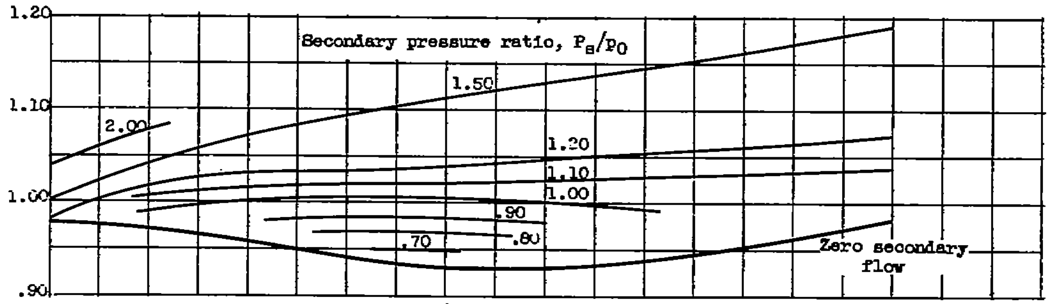
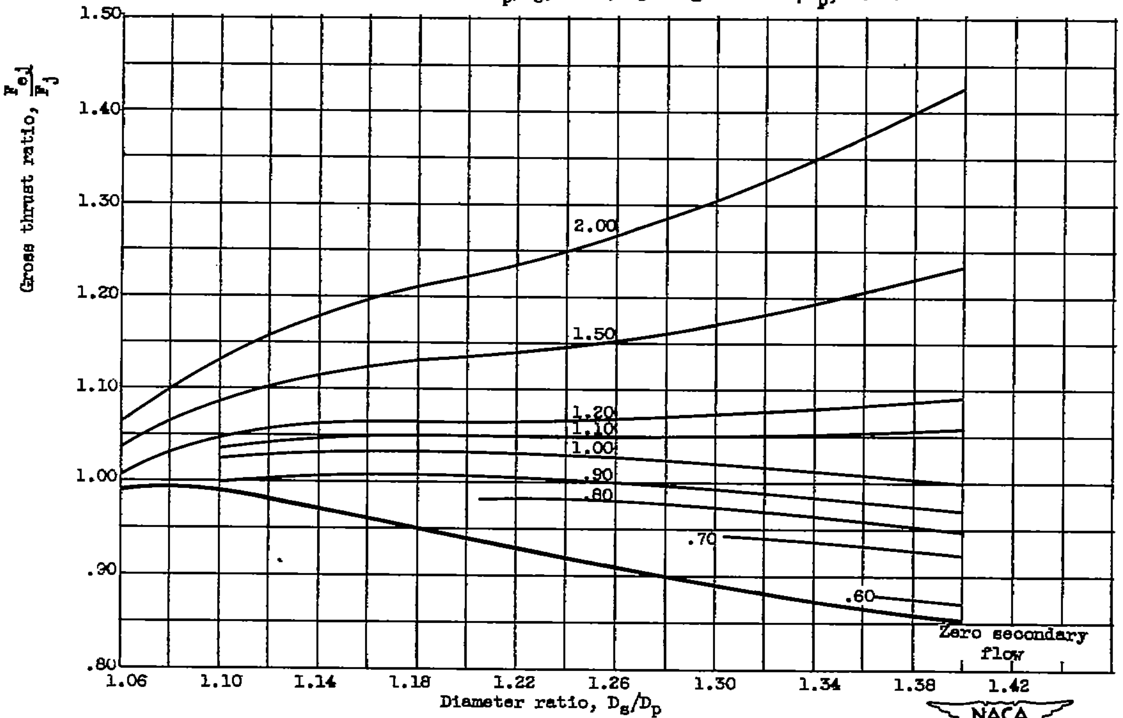


(d) Primary pressure ratio P_p/p_0, 2.0; spacing ratio S/D_p, 1.60.

Figure 9. - Effect of diameter ratio on ejector gross thrust ratio.



(e) Primary pressure ratio P_p/p_0, 3.50; spacing ratio S/D_p, 0.40.



(f) Primary pressure ratio P_p/p_0, 3.50; spacing ratio S/D_p, 0.80.

Figure 9. - Concluded. Effect of diameter ratio on ejector gross thrust ratio.

SECURITY INFORMATION

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